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Watershed Work Plan
Honolua Watershed

MAUI COUNTY, HAWAII
JANUARY 1972

Prepared under the authority of the Watershed Protection & Flood Prevention Act
(Public law 566, 83rd. Congress, 68 Stat. 666) as amended.

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE

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HONOLUA WATERSHED

Maui County, Hawaii

Prepared Under the Authority of the Watershed Protection and Flood Prevention Act (Public Law 566, 83rd Congress, 68 Stat. 666) as amended.

Prepared by:

West Maui Soil and Water Conservation District

and

County of Maui

With assistance by:

U. S. Department of Agriculture, US Soil Conservation Service

U. S. Department of Agriculture, Forest Service

January 1972

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HONOLUA WATERSHED

County of Maui, Hawaii

SUMMARY OF PLAN

The Honolua watershed is located on the western end of the island of Maui, Hawaii. The watershed covers an area of 24,800 acres. Present land use pattern includes 67 percent in forest land, 27 percent in agricultural land, 4 percent in grassland, and 2 percent in urban use.

The watershed work plan was prepared by the West Maui Soil and Water Conservation District and the County of Maui, the sponsoring local organizations. Technical assistance was provided by the Soil Conservation Service and the Forest Service of the U. S. Department of Agriculture.

The primary objectives of the project are to provide effective land treatment on watershed land and to prevent floodwater and sediment damage in the flood plain and discoloration of the ocean along the coast. The works of improvement for protection and development of the watershed will be installed during a five-year period. The total installation cost is estimated to be $4,319,510. The Public Law 566 share is $3,238,120, while the share borne by other funds is $1,081,390. In addition, other funds will bear the entire cost of operation, maintenance and replacement of the structural works at an estimated annual cost of $29,280.

Land Treatment Measures

Land treatment measures will include soil and water conservation practices needed to reduce runoff and sediment production, maintain favorable soil conditions and productivity, and maintain cover for soil protection on grasslands and forest land.

Major emphasis will be placed on accelerating installation of land treatment measures to control runoff from croplands. Improved pasture management will reduce erosion from gulches and other areas used for pasture.

Total cost of installing these measures is estimated at $361,180. This will include $77,100 of federal (PL-566)

funds for providing accelerated technical assistance to land owners and operators.

Structural Measures

The structural measures in the plan include 3,900 feet of open channel, 8 debris basins, and 4,290 feet of concrete-lined floodwater diversions.

The total cost for installation of all structural measures is estimated at $3,958,330. The federal (PL-566) share will be $3,161,020, and the share from other funds will be $797,310.

Comparison of Benefits and Costs

The estimated average annual benefits attributable to structural measures will be $370,660. These include $337,490 from damage reduction benefits and $33,170 in secondary benefits.

The estimated average annual cost of these measures will be $243,190.

The ratio of benefits to costs is 1.5 to 1.0.

Cost Sharing for Structural Measures

All costs for structural works of improvement are allocated to flood prevention. PL-566 funds will bear all costs for construction, engineering services and project administration. Other funds will bear all costs of land rights.

Project Installation

The installation of land treatment measures will be the responsibility of individual land owners or operators. Technical assistance will be provided by the Soil Conservation Service and the State Division of Forestry through cooperative agreements with the West Maui Soil and Water Conservation District. Cost of eligible agricultural measures may be shared through the Rural Environmental Assistance Program and other funds.

The installation of structural measures will be the responsibility of the County of Maui with technical assistance from the Soil Conservation Service.

Operation and Maintenance

Land treatment measures will be maintained by owners and operators under agreement with the West Maui Soil and Water Conservation District.

The structural measures will be operated and maintained by the County of Maui.

DESCRIPTION OF WATERSHED

Physical Data

Location

The Hawaiian Archipelago extends more than 1,600 miles across the Pacific Ocean on a northwest-southeast axis. Maui is one of the eight major islands at the southeast end of this chain of islands. The island of Maui is located near 20°55' north latitude and 156°38' west longitude approximately 100 miles southeast of Oahu and the city of Honolulu. The islands of Maui, Molokai and Lanai form the County of Maui in the State of Hawaii. The adjoining towns of Wailuku and Kahului form the principal urban center of Maui and are the focal point of political and economic activities in the county.

The Honolua watershed is in the West Maui Soil and Water Conservation District, approximately 25 miles by road from Wailuku and is located on the northwest side of the island. (See Project Map.) The watershed is approximately five miles north of Lahaina, a famed and popular seaport town of the 19th century, and one mile north of the rapidly growing Kaanapali resort area.

The Honolua watershed is 24,800 acres in size and generally triangular in shape. The upper point of the watershed is Puu Kukui, the highest peak in the West Maui mountains (elev. 5,788 feet). Twelve major gulches fan outward to form the ten-mile-long section of the watershed coastline (see Project Map). A narrow stream winds its way down each gulch. The streams in the northern section are for the most part perennial such as the Honokohau, Honolua and Honokahua, while only the Honokowai Stream is perennial in the southern section. The others are dry except after heavy rains. Sandy beaches separated by rocky peninsulas dominate the coastline.

Climate

The Hawaiian Islands, located at the northern edge of the Tropics, enjoy a mild subtropical climate. Arctic waters drift into the region from the Bering Sea and cool the sea breezes that sweep over the land creating milder temperatures than normally would be expected at this latitude. The mean temperature at Lahaina is 77.5° F. with an average minimum of 61.4° F. and average maximum of 87.6° F.

The Honolua watershed, located on the leeward side of the island, receives less rainfall from the prevailing northeasterly trade winds than does the windward northern coast. The average annual precipitation at Puu Kukui is about 400 inches decreasing to about 20 inches along the southern coastline. Rainfall along the northern coastline averages about 30 inches per year.

The Hawaiian Islands are exposed to three classes of weather disturbances that produce torrential rains. These are the cold-front storms, the cyclonic "kona" storms, and the rarer tropical storms or hurricanes. The major storms usually occur during the months of October through May.

The growing season is 12 months long with only a slight reduction in the growth rate during the winter months. This is due to the relatively uniform temperatures and day-lengths experienced throughout the year.

Geology

The Honolua watershed lies on the northwest slopes of the West Maui mountains. These mountains were formed by volcanic action. The active volcanoes were the "central type" rather than the "fissure type" and dikes radiate in all directions from the ancient caldera.

Extruded basalts constitute the mass of the mountain foundation. The presence of soils 20 feet deep or more indicates the volcano probably became extinct in Pliocene or earliest Pleistocene time. The West Maui mountains have since been eroded to form steep canyons.

The island passed through a series of submergences and emergences as shown by the presence of marine fossils up to elevations of 250 feet and by the loss of soil through marine erosion at higher elevations.

Cover Conditions

Much of the watershed is in forest cover. This includes land within the West Maui Forest Reserve and land outside the reserve but in forest cover. The forest land is in good hydrologic condition except for small areas in forested gulches outside of the forest reserve where vegetative cover has been destroyed.

The major species of plants in the forest area include the following trees and shrubs: ohia (*Metrosideros collina*), koa (*Acacia koa*), Christmas berry (*Schinus terebinthifolius*), sugi (*Cryptomeria japonica*), Norfolk-Island pine (*Araucaria*

heterophylla), Monterey cypress (Cupressus macrocarpa), Eucalyptus species, kiawe (Prosopis pallida), kukui or candlenut tree (Aleurites moluccana), false staghorn fern (Dicranopteris linearis), guava (Psidium guajava), lantana (Lantana camara), koa haole (Leucaena glauca) and honohono (Commelina diffusa).

The grasses include Dallisgrass (Paspalum dilatatum), Hilograss (Paspalum conjugatum), and yellow foxtail (Setaria geniculata). In addition, forage plants have been introduced such as guineagrass (Panicum maximum), bermudagrass (Cynodon dactylon), kikuyugrass (Pennisetum clandestinum), and pangolagrass (Digitaria decumbens).

The major crops raised on the cultivated land are sugar cane and pineapple. Much of the grassland areas are used for pastures.

Soils

The soils of the watershed area can be divided into two general areas. The first and most extensive is the very shallow, steep to extremely steep upland soils formed under a forest cover.

The second area is intensively cultivated with sugar cane and pineapple. This area includes areas adjacent to the ocean where the hotels and urban areas are located. The soils in this area are the Honolua-Olelo and Waiakoa-Keahua-Molokai associations.

The general soil map (Figure 1) shows the soil associations of the watershed. These are described as follows:

Honolua-Olelo Association: This association consists of well-drained, fine-textured soils developed in material weathered from basic igneous rocks. These soils are on gently sloping to moderately steep uplands. Elevation ranges from 500 to 3,000 feet. Annual rainfall is 40 to 100 inches. This association comprises about 8 percent of the watershed. Most of the area is in grass and shrubs with some acreage in pineapple.

In this association, the Honolua soils make up about 61 percent of the area and Olelo soils 39 percent.

Honolua soils have a dark-brown, silty clay surface layer. The subsoil is a dark reddish-brown silty clay.

Olelo soils have a dark reddish-brown silty clay surface layer. The subsoil is dusky-red silty clay. The substratum is soft weathered rock.

Waiakoa-Keahua-Molokai Association: This association consists of well-drained moderately fine-textured soils developed in material weathered from basic igneous rocks. Elevation ranges from near sea level to 1,500 feet. Annual rainfall is 20 to 70 inches. This association comprises about 27 percent of the watershed. Almost all of the acreage is in sugar cane and pineapple.

In this association, the Alaeloa soils make up about 36 percent of the area, Kahana about 41 percent, Lahaina about 21 percent, and others about 2 percent.

Alaeloa soils have a dark reddish-brown silty clay surface layer. The subsoil is a dark-red silty clay.

Kahana soils have a dark reddish-brown silty clay surface and subsoil.

Lahaina soils have a dark reddish-brown surface layer and a dusky-red and dark reddish-brown subsoil.

Rock land-Rough Mountainous Land Association: This association consists of very shallow soils on steep to extremely steep intermediate and high uplands. Elevation ranges from sea level to 5,788 feet. Annual rainfall is 20 to 400 inches. This association comprises about 65 percent of the watershed. Almost all of this acreage is in forest.

Most of the land in this association is Rough mountainous land. Over much of the area the soil mantle is very shallow and is usually less than 10 inches deep over saprolite. Vegetation consists of trees, shrubs and ferns.

This land provides the bulk of the water supply for the area and supports various types of wildlife.

Economic Data

History of the Area

The Honolua watershed is an integral part of the Lahaina District. Politically, socially and economically, the watershed has a significant influence in the Lahaina District. Lahaina was once a thriving, bustling community of governmental, industrial and economic importance for it was the early capital of the Hawaiian Islands.

Four centuries of unrecorded history intervened between the great Polynesian migration to Hawaii and the arrival of Captain James Cook, the British explorer who "discovered" the islands in 1778. Through these hundreds of years, the Hawaiians in Lahaina District stabilized their way of life at a level at which land and sea resources would sustain their social organization, primitive techniques and simple economy.

Following the discovery of rich sperm whale grounds off the coast of Japan in 1820, Lahaina became a center of the Pacific's whaling industry. Whalers were attracted to the islands as a place for repairs, provisions, refuge and relaxation during the winter months when stormy weather dominated the North Pacific. During the golden age of whaling in Hawaii, more than a hundred ships at a time lay at anchor in the Lahaina Roadstead.

The final decline of whaling in Lahaina, the Pacific and, in fact, all oceans of the world began in 1859 with the introduction of kerosene, celluloid and steel. The effect on business in Lahaina District was drastic. Prices tumbled. Cattle and staple products became comparatively worthless. Agriculture in the district entered a most uncertain state of transition.

The advent of sugar and pineapple production in the late 1800's brought a new surge of economic development. With sugar as Maui's major agricultural pursuit in the 1900's, Lahaina District emerged as a center of industrial development. Then in the early 1950's, another lapse in economic growth followed the shift of industrialization to the Kahului Harbor and airport facilities. Many people left the area seeking a better livelihood. As a consequence, the only people remaining in the district were those connected with the sugar and pineapple industries.

Today, Lahaina District is experiencing another economic boom, based this time on the development of its tourist industry. Maui County developed and adopted a General Plan

in 1968 designed to promote orderly growth and preserve the national landmarks and environment in the district. The General Plan was financed in part through an urban planning grant from the Housing and Home Financing Agency under the provisions of Section 701 of the Housing Act of 1954, as amended.

The General Plan is composed of a number of elements among which are:

1. Land Use Plans - existing and proposed, provide detailed allocations of land resources based on the district's overall needs.

2. The Public Facilities Plan provides an analysis of land proposals for the locations and uses of present and future public buildings and systems.

3. Recreation Plan analyzes the recreational facilities and proposes means for improving and expanding the present system.

4. The Circulation Plan provides an analysis of land proposals for the improvement and expansion of regional traffic arteries, terminals and other modes of transportation.

5. The Public Utilities Plan provides an analysis of land proposals for the improvement and expansion of sewer, water and drainage systems.

The County of Maui has been authorized a Resource Conservation and Development Project under Public Law 87-703. It is called the Tri-Isle RC&D Project and includes project actions which will improve the natural resource base and provide for economic improvement and social enhancement. The U. S. Department of Agriculture will provide financial and technical assistance.

Land Use Pattern

Present land use in the watershed is distributed as follows:

Use	Acreage	Percent of Total
Cultivated crops:		
Pineapple	4,122	16.6
Sugar cane	2,400	9.7
Other crops	25	0.1
Forest reserve	8,900	35.9
Other forested area	7,753	31.3
Pasture	1,000	4.0
Residence-apartment and hotels	500	2.0
Other urban	100	0.4
	24,800	100.0

Forest land comprises 67 percent of the watershed, 27 percent of the land is cultivated crops, 4 percent is grassland and 2 percent urban.

The State Land Use Law, passed by the State Legislature in 1961, provided for zoning of all lands by uses. It empowered the State to classify and regulate uses to urban, rural, agricultural and conservation purposes. The main objectives of the law were to protect prime agricultural land from needless residential development and to induce orderly urban development.

The County of Maui, with its recently adopted General Plan for the Lahaina District, is attempting to create a logical pattern of land use by giving careful consideration to the needs of each segment of the community. They are also attempting to establish uses that are harmonious with each other and with the total environment as well. The existing land use and future land use are shown in figures 2 and 3. Future land use will include residential, commercial and hotel development interspersed with public parks and green belts. Lands above the proposed realignment of Honoapiilani Highway will continue in agricultural and forest use.

Land Value and Ownership

Most of the land in the watershed (22,350 acres) is privately owned. There is no federally owned or managed

land. The State of Hawaii owns approximately 950 acres of forest land in the watershed; 750 acres are within the forest reserve and 200 acres outside of the forest reserve. The State also owns 1,500 acres of agricultural land in the Napili 4-5 and Honokowai areas. This land is presently leased to private operators.

In 1965, cropland within the watershed sold for $0.50 per square foot or approximately $22,000 per acre. The market value of residential zoned land is estimated to be approximately $120,000 per acre. Commercial land is estimated to be approximately $131,000 per acre. The high value of land is attributed to growth factors associated with resort-hotel developments located on the watershed coastline. Beachfront properties, during the past few years, have commanded a premium price ranging from $4 to $6 per square foot.

Land ownership in the watershed is distributed as follows:

	Percent	Acres
Private (outside forest reserve)	57.2	14,200
Forest Reserve (Private)	32.9	8,150
Forest Reserve (Public)	3.0	750
Other Public Lands	6.9	1,700
Total	100.0	24,800

Population and Population Characteristics

In 1852, the demand for laborers in Hawaii's sugar industry resulted in the importation of workers. They were first imported from China and later from Portugal, Japan, the Philippines and other countries. Large-scale immigration began in 1876 and soon foreign-born residents outnumbered natives. Ethnic composition of the population changed rapidly.

Most of the arrivals were young unmarried males. Interracial marriage, already common, became even more frequent. By 1900, two years after the Republic of Hawaii was annexed to the United States, only 38.3 percent of the population was Hawaii born and only 24.4 percent was racially Hawaiian or part Hawaiian.

During 1960 to 1965, Lahaina District increased its population approximately 14 percent. Population in Honolua watershed has remained comparatively static during the past decade and is presently estimated at 1,000. Its multiracial composition, represented by a wide variety of Caucasian and Oriental races, is typical of the State's population.

According to the General Plan for Lahaina District, the watershed population should reach approximately 5,000 by 1990. These projections were based on the number of employees needed to support the anticipated growth of tourism.

Employment

In 1960, industry in Lahaina District employed 1,250 workers who supported 3,400 persons including themselves. These workers primarily were associated with producing sugar cane and pineapple. In 1990, it is estimated that 15,800 workers will support 29,500 persons in the district including themselves. The majority of these 15,800 workers will be employed by the tourist industry, and residential areas will expand to house these workers.

The per capita income within Lahaina District, adjusted for inflation, is expected to rise at a moderate rate because increased wages will be necessary if the district is to attract and hold the necessary talent to service the tourist trade.

Agriculture and Related Activity

Historically, agriculture in Honolua watershed has been an important economic activity dominated by sugar cane and pineapple production. Pineapple fields cover approximately 4,100 acres of watershed land extending north from Kaopala subwatershed. Sugar cane, on the other hand, is grown on 2,400 acres of watershed land within the Kahana, Mahinahina and Honokowai subwatersheds and extends beyond the southern boundary of the watershed.

Pineapple operations account for approximately 10 percent of the State's total pineapple production. Hawaii, in turn, accounts for about 40 percent of the world's total production of canned pineapple. Conversely, in 1969, approximately one percent of Hawaii's total annual raw sugar output was produced in the watershed area. Hawaii is the largest sugar producing state in the nation and provides 10 percent of the total United States requirement.

These industries are presently experiencing internal problems; however, the major problem is one of labor parity. Even though Hawaiian agricultural workers are among the world's highest paid, on the year-round basis, they are not paid as much as construction workers, some tradesmen, or service industry workers in Hawaii. Liberal fringe benefits have helped to keep some employees in the sugar and pineapple industries, but the younger workers are not returning to work on the plantations. Continued mechanization and the need for higher skill levels can make jobs more attractive, but this has to be combined with higher productivity and higher pay.

Even in the midst of its present problems, agriculture still remains an important economic entity of the watershed. The following table depicts the average annual gross value of watershed agricultural enterprises:

Enterprise	Number of Units	Average Annual Gross Value
Pineapple	1	$2,200,000
Sugar cane	1	1,625,000
Other crops	5	5,000
Beef	16	50,000
Total	23	$3,880,000

Forest Activity

When Captain Cook landed in Hawaii in 1778, forests covered most of the land and supplied the Hawaiians with wood for fuel, structures, tools, and canoes and material for cloth, utensils and food. Grass and forage plants were not extensive and no grazing animals roamed the islands.

Cook introduced goats, and a few years later Captain Vancouver left both sheep and cattle. With no natural enemies and protected by a strict tabu, these animals increased rapidly. Soon they were widespread on all the islands. Uncontrolled browsing and hoof damage to roots so injured native trees and shrubs that thousands of acres were denuded, exposing the land to severe erosion and endangering the water supply.

By the late 1800's the situation became so critical that strong conservation organizations were formed to reclaim these areas and to press for legislative control. In 1893, conservation-minded organizations formed an agency, later called the Bureau of Agriculture and Forestry, to rehabilitate these areas. One of the first steps was the establishment of the forest reserves in the most critical watershed areas. The reserves were fenced. Wild cattle, sheep and goats were eliminated and tree planting was started.

Today, the value of the forest lands for watershed protection, recreation and wildlife habitat exceed their value for timber production.

Water from forest reserve lands is used for irrigation within the watershed and to irrigate 3,500 acres of adjacent land. Water from this watershed is also used for domestic purposes.

There is a growing interest in the development of mountain recreation activities within this watershed such as hiking trails, camping and picnic areas, lookout points, historic sites and wilderness parks.

The timber growing potential is good, as demonstrated by plantings of exotic trees over the years. However, harvest of timber products is a very minor activity at the present time for two reasons. First, only a small part of the forest land is stocked with commercial timber, although about 9,800 acres are classified by the forest survey as being capable of producing timber crops. Secondly, expansion of the islands' small sawmilling industry will depend upon

the expansion of local markets and perhaps export markets for specialized products for which the timber is useful.

Timber harvesting on a sustained yield basis would be feasible over much of the area without damage to, and often enhancing watershed, recreation, and wildlife habitat values. A large forestration effort would be required to develop a significant timber resource, but landowners have shown little interest in developing this resource.

A policy stemming from the need to protect the water resource has restricted livestock grazing in the forest reserve. Most of the forest lands outside the reserve are grazed. With adequate controls and a sound system of grazing management, forested areas can provide additional forage for the livestock industry without serious soil erosion and flood runoff. In the steep forested gulches between cultivated fields in the lower watershed, however, watershed protection and esthetics should be primary objectives of management.

Tourism

Since the development of Kaanapali resort center on the fringe of Honolua watershed, the visitor industry has shown signs of growth that may soon make it the primary employer in the watershed. The rate of increase in the number of visitors to Maui is phenomenal. The increase was 50.1 percent for 1963 over 1962, and 42.3 percent for 1964 over 1963. Maui's share of some 92,000 visitors in 1963 was barely 28 percent of total westbound visitors and less than 21.5 percent of total state visitors. In 1964, Maui's share of 131,000 achieved an all-time high (since 1951) of 32.3 percent.

To accommodate the increasing visitor flow and anticipation of greater flows, tourist facilities in the watershed have increased from 44 hotel rooms in August 1962 to 346 at the end of 1966. Approximately 100 units are presently in the design or construction stage. With significant expansion of tourism at Kaanapali and the Honolua watershed, Maui County has reversed a decade of consistent decrease in both labor force and employment and reduced its monthly average unemployment rate of 5.8 in 1962 to 4.4 in 1967.

Tourism in Honolua watershed has undoubtedly come a long way since 1960. It no longer derives its momentum from a specific event that cannot be repeated, such as the advent and subsequent impact of statehood or the dedication of Lahaina as a national historical landmark. Its momentum may now be attributed to intrinsic strength within the

industry. This strength is expected to increase rather than decrease. Jet travel and ideal climatic factors inherent to Honolua have contributed to this phenomenal growth. Joint promotion by government and business is another principal catalyst. These factors should continue to sustain and advance development of Honolua's tourist industry.

Public Utilities

Water Systems

Water development in Honolua watershed was started by the early Hawaiians who diverted stream flows for use in their taro fields located in some of the major stream valleys and coastal reaches. Water rights of 1 MGD for taro production are still observed at Honokohau Stream.

In the early 1900's, stream flows from perennial streams such as Honokohau, Honolua and Honokowai were diverted by ditches and tunnels for the cultivation of sugar cane. Since then, many wells have been developed to meet the agricultural and domestic water needs of the watershed and district. Water systems both publicly and privately owned serve Honolua watershed.

Although most of the water in private systems is used for irrigating sugar cane lands, it also supplements the public systems. The public and private systems both use surface and high level ground water for domestic uses.

Sewer Systems

At present, the project area has no sewer system and the existing developments use cesspools.

However, in 1965, a master sewer plan for the area was prepared by the County of Maui. At that time, primary sewage treatment plants were proposed at Napili and Honokowai; but due to appropriation restrictions, the proposed Napili plant has been eliminated and that system has been integrated with the plant proposed for the Alaeloa area.

Transportation

Land

Air and sea travel will definitely play a larger role in the future. Conventional vehicular traffic will continue to be the most important and costly element within the region's overall transportation scheme.

Honoapiilani Highway, the major artery linking the watershed and the Lahaina District with the commercial airport at Kahului, is the backbone of the land transportation system.

Population and traffic projections made by the County of Maui and the Hawaii State Department of Transportation indicate that a new alignment is necessary to serve the needs of Honolua watershed and the West Maui region through 1990.

Air

Air transportation will become increasingly important as the watershed and region's future growth is realized. Presently the area is served by a privately owned airfield at Kaanapali, located on the southern fringe of Honolua. Because of its limited facilities and short runway, this airport is confined to use by licensed air taxi operators and highly qualified individuals.

A precise location has yet to be chosen for a general aviation field. A site above Puukolii Village in Mahinahina subwatershed, tentatively recommended in the General Plan for the Lahaina District, has caused much controversy throughout the Lahaina District. The feasibility of this facility will be determined by a two-year Hawaii State Department of Transportation study of statewide requirements for commercial air traffic facilities.

Sea

Residents of the watershed and West Maui take full advantage of their protected and attractive waterfronts for this area offers some of the best boating possibilities in the State. The most important docking and launching facilities will be located at Lahaina town. Because of the expected increase in boating activities, the General Plan recommends that launching points be evenly distributed throughout the region.

Land Treatment Data

Cropland

Cropland in the watershed consists of 4,122 acres used for pineapple production and 2,400 acres in sugar cane. There are also about 25 acres used for small orchard, vegetable and flower growing enterprises.

These uses of the land are long established and are expected to continue except for 50 acres of pineapple and sugar cane lands which have been rezoned for urban use under the Maui County master plan for West Maui.

Of the pineapple and sugar cane land, about 85 to 90 percent consists of gentle to moderate slopes and is included in capability classes II, III, and IV. The balance of the acreage consists of steep slopes which fall into capability class VI. Some small areas of the class VI land have been retired to grass and others are planned for this treatment. However, several areas lie on narrow strips within fields, consisting of short, steep slopes intermingled with larger areas of more favorable topography. Under large-scale mechanized agriculture, it is not practical in most cases to separate these areas.

The hydrologic condition of cropland varies during the growing cycle. When the fields are bare or newly planted they are most vulnerable to erosion for a period of about 3 to 7 months. At this time sediment and floodwater runoff can be considerable during heavy rains. As the plants mature they provide significant protection to the fields against erosion. Pineapple is planted for a period of 40 to 50 months and sugar for a period of 20 to 30 months. Field roads, however, remain unprotected and are the greatest source of sediment when the plants mature. With good land treatment, including changing field and road layout, erosion from cropland can be reduced considerably.

The West Maui Soil and Water Conservation District has encouraged its cooperators to apply needed conservation measures and recognized those who have done so. Maui Pineapple Company was selected as the District's outstanding cooperator and shared first prize in the 1968 Goodyear Contest for SWCDs for installing good land treatment measures in newly planted fields.

Ninety eight percent of the land in the watershed is covered by SWCD agreements. Thirty three per cent of the planned conservation practices are applied, and the balance is scheduled for installation over the five year installation period.

SCS PHOTO 4-1023-6

Contour blocks and sodded waterways reduced erosion damage in this pineapple field in the Napili area.

Forest Land

Practically the entire area inside the forest reserve is native forest of scrubby ohia trees with associated vegetation. Native forest extends down into some area below the reserve but, for the most part, the forest vegetation in the lower lands consists of brushy types.

There are about 550 acres of tree plantations, mostly outside the forest reserve. These are mainly sugi (Cryptomeria japonica), Norfolk-Island-pine (Araucaria heterophylla), Monterey cypress (Cupressus macrocarpa), and Eucalyptus species.

Protection of watershed values has been the major objective of management of the forest lands for many years, and practically all the forest land is in good hydrologic condition. Exceptions are small areas in forested gulches below the forest reserves where livestock concentrations have damaged the vegetative cover. In such areas, soils are partially barren and compacted, contributing to greater and faster storm runoff and erosion. These areas can be improved.

In several of these gulches, grass seeding and proper livestock management can protect the soil and reduce runoff. In other areas, such as the lower reaches of Papua and Pahakupule Gulch and Honolua Stream, barren eroded spots are still contributing sediment even though these areas have not been grazed for many years. Here an estimated 400 acres are in need of reforestation.

A Memorandum of Understanding exists between the West Maui Soil and Water Conservation District and the Hawaii Department of Land and Natural Resources concerning forestry land treatment. Through its Division of Forestry, in cooperation with the U. S. Forest Service, technical assistance is provided to private landowners on management of their forest lands.

Fish and Wildlife Resource Data

Sea life along the watershed coastline is similar to that of most tropical islands where colorful fish and other marine life live in and around the reefs. In recent years residents say that there has been a marked reduction in the number of fish and other marine organisms due to increased activity by man and sediment deposition. However, fishing and "squidding" (octopus gathering) continue along the coast providing recreation and food.

Commercial and sport fishing occurs in the navigable waters farther out to sea and is dependent upon the food chain which includes the marine life in shallower coastal waters.

Wildlife in the watershed is typical of most of Hawaii. There are many varieties of small birds such as doves, sparrows and mynahs. Some rare species of Hawaiian birds are found in the heavily forested areas, and pheasants are occasionally seen in the cultivated fields. Small animals such as mongooses and rodents are common in the lower populated areas while wild pigs inhabit the upper restricted forest areas.

Hunting is almost nonexistent in this watershed since most of the land is not open to the public.

Mineral Resource Data

In the northern one-half of the watershed project area, north and east of Napili Bay, ferruginous bauxite (iron-aluminum) can occur between the elevations from 200 to 1,000 feet and extend 2 miles inland. The deposits average 6 feet in thickness, and are covered with up to 20 feet of wind-blown nonbauxitic material. Tonnage estimates for the whole deposit, which extends farther north than the watershed project, reportedly are a minimum of 9 million dry tons and a maximum of 20 million dry tons of bauxite. Average grade of bauxite was estimated from drill samples to be 38 per cent aluminum oxide, 22 per cent iron oxide, 7 per cent silicon oxide, and 4 per cent titanium oxide. The area is all privately owned.

Archaeologic Resource Data

The Hawaii Revised Statutes, Chapter 6, requires archaeological survey work in proposed construction areas when specified by the Department of Land and Natural Resources.

Preliminary evidence suggests a high probability that sites of archaeological and historical significance exist in the Honolua Project area and the Department has ruled that a survey is needed.

The Bishop Museum in cooperation with the County of Maui is making a preliminary survey of the island and is directing special attention to the Honolua Watershed.

SCS PHOTO 4-611-9

Bridges along Honoapiilani Highway frequently have been damaged or rendered temporarily impassible.

WATERSHED PROBLEMS

Honolua watershed is divided into 12 major subwatersheds, each with a narrow winding channel that drains into the ocean. Principal problems in the watershed are attributed to intense local rainstorms that cause overland flooding, sheet erosion and sediment pollution of coastal waters.

With the advent of mechanized farming operations and the subsequent conversion of additional lands to the production of pineapple and sugar cane, the cultivated land and flood plain are now vulverable to excessive damage. Large fields of sugar cane and pineapple are cleared in short periods of time by harvesting and replanting operations. Even with immediate replanting, these areas are open and susceptible to damage for extended periods of time before new growth provides any significant protection.

SCS PHOTO 4-758-11

Recently harvested fields and fields prepared for planting are most susceptible to erosion damage.

SCS PHOTO 4-28-5

Newly planted fields of sugar cane and pineapple need protective measures because young plants do not provide significant protection against erosion for 4 to 6 months after planting.

Cultivation of sugar cane and pineapple on moderately steep lands directly above the coastal plains has increased runoff and erosion from these land areas. Minimal use of crop residue, characteristic of sugar cane field operations, also contributes to erosion thus increasing sediment production and damage to watershed coastal areas. Although most of the forest land is in good hydrologic condition, there are exceptions on small areas outside the forest reserve where bare and compacted soils contribute to greater and faster storm runoff and erosion.

Flooding is a major problem in the watershed. Since 1955, 12 major floods have inflicted suffering and despair upon watershed residents. Major flooding in Honolua is presently concentrated in the Napili, Mahinahina and Honokowai subwatersheds. However, minor flooding is experienced in low-lying areas of the Kaopala and Kahana subwatersheds. Extensive damages to agricultural, residential, commercial and resort properties have resulted from the high-velocity, sediment-laden flood flows through the area.

The storm of December 1964, a typical large storm, was estimated to occur approximately once in 20 years. It caused a total of $233,300 in damages--$106,000 in agricultural damages and $127,300 in community damages along the coast. During this storm, extensive erosion and sediment damages were inflicted in all subwatershed areas. Community damages consisted of floodwater and sediment damages to residences and resort-commercial developments located principally at Napili, Honokowai, Mahinahina and Kaopala. Many lives were threatened by this storm which sent raging flood currents through these residential and resort-commercial areas. Sediment polluted the beach and coastal water areas bordering major streams in the watershed. The intensity of pollution was such that swimming beaches were not used by residents and visitors for at least one month. People left the area. Hotel reservations were prematurely cancelled and businesses dependent on the tourist trade suffered financial losses.

SCS PHOTO 4-975-12

Flood water transported this car 600 feet to Napili Bay, damaged building and grounds near the beach and destroyed the beach area.

Shoreline sediment pollution is a major problem associated with flooding. Extensive sediment deposition and discoloration of the ocean along the watershed shore areas occur with every heavy rainfall. As a result, beaches in these areas are degraded by the presence of silt, not only in the water, but mixed with the beach sand as well.

The ocean, for a distance of 1/4 to 1/2 mile, stays red for two to four weeks following the normal rainstorm. The time duration of shoreline pollution caused by a rainstorm is largely dependent on the storm's magnitude, the existing ocean currents, and the reef formation bordering each subwatershed shoreline area. In some of these areas, off-shore currents and reef formations are such that they allow the sediment-laden water to dissipate relatively fast. In others, the off-shore current prevents the deposited sediment from being carried further out to sea.

These physical problems of flooding and sediment pollution are, in fact, threatening the economic existence of the watershed community. Many families are dependent upon the tourist trade for a livelihood and have based much of their hopes for a better future on the growth and development of the tourist industry. However, the extent of watershed resort development is primarily dependent upon the maintenance and preservation of the watershed's ideal tropical environmental amenities that initially attracted capital investment for the development of resort facilities and other supporting businesses.

The environment of Honolua is rapidly deteriorating because of this problem. According to fishermen and residents, sediment pollution over the course of about a decade has reduced the productivity of the ocean area bordering Honolua. Marine biologists studying the effects of sediment on marine life in Kaneohe Bay, island of Oahu, claim that sediment pollution is a deterrent to proper coral growth and thus considerably reduces the fish fauna in a polluted area.

Erosion causes crop losses when young plants, fertilizers and topsoil are washed away by heavy rains. The cost of repairing and replanting fields and cleaning up flood damages has been high. Flood damages in recent years are summarized in the following table:

FLOOD DAMAGES CAUSED BY PAST STORMS

Date of Storm	Damages in Dollars: Agriculture	Other	Total	Subwatershed
Dec. 19-21, 1955	10,000	-	10,000	Honokowai
Jan. 12-16, 1956	800	-	800	Honokowai
Jan. 12-18, 1959	1,000	-	1,000	Honokowai
Oct. 31-Nov. 3, 1961	385,000	65,000	450,000	All
July 22-23, 1964	-	300	300	Honokowai
Dec. 19-20, 1964	106,000	127,300	233,300	All
Feb. 4-5, 1965	5,500	21,500	27,000	Napili, Honokowai
Mar. 22, 1965	-	2,500	2,500	Napili
Apr. 13, 1965	500	10,500	11,000	Napili
May 2, 1965	5,100	1,000	6,100	Napili
Mar. 17, 1967	36,000	149,200	185,400	Napili
Apr. 16, 1968	-	18,400	18,400	Honokowai
Total	550,100	395,700	945,800	

SCS PHOTO 4-611-11

Sediment washed from the fields is deposited in homes, yards, streets and commercial establishments.

SCS PHOTO 4-611-10

This home near Mahinahina stream was undercut by bank erosion. The damage was repaired and the home is still in use.

PROJECTS OF OTHER AGENCIES

The County of Maui has completed emergency bank protection along the Mahinahina Stream immediately below Honoapiilani Highway. The rock-masonry work will check further streambank erosion in this area pending installation of Mahinahina Stream channel improvement.

The State Division of Highways has selected a new location for the Honoapiilani Highway and started final design work. Construction of the new section of highway is scheduled for fiscal year 1972. This will be a federal aid project with funds received through the Federal Highway Administration.

Plans for the watershed project have been coordinated with the plans for the new highway. The highway fill across Mahinahina and Pohakukaanapali gulches will be designed and built to serve as dams for the proposed desilting basins. The earthfill and culverts will be installed by the highway department as part of their works. These two culverts will be designed and built so that a riser structure can be added to create a sediment pool after the work plan has been approved for operations.

Maui County will construct a temporary channel which will divert Honokowai Stream to the north. The Highway Division will then construct the bridge as proposed in this work plan rather than over the existing stream.

Improvement of the Honokowai channel between the present Honoapiilani Highway and the ocean has been designed by a consulting engineer for private development. The SCS furnished design and freeboard flow rates and proposed channel dimensions so that plans for the privately developed channel will be compatible with plans developed for the watershed project.

PROJECT FORMULATION

Project Objectives

Formulation of the project work plan was based on objectives of the sponsoring local organizations. These objectives include flood prevention, proper land use, flood plain management, reducing erosion and sedimentation and enhancing the social and economic development of the community.

The sponsors and the Service have agreed that the desired level of flood protection should be the 100-year frequency of occurrence because loss of life is a constant and serious threat, and this level of protection will prevent most of the damages in the flood plain.

Land Treatment Measures

Land treatment measures are necessary on cropland to control erosion and reduce sediment pollution. Treatment is also needed on pasturelands to improve vegetative cover and prevent soil erosion. Reforestration and other cover improvement is needed on small acreages within the forest and brush covered drainages. Technical guides have been developed describing soil capabilities and applicable land treatment measures.

Major emphasis will be placed on practices designed to control runoff from croplands. This will help to minimize sediment pollution of the coastal waters, which is one of the major objectives of the project. Also, it will assist land operators in the watershed to comply with state water quality standards.

Structural Measures

Water storage and flood retarding structures are not feasible for this project where heavy rain produces large volumes of runoff with high peak flow rates. Steep land slopes restrict flood pool sizes, and the flood pools that could be developed are too small to significantly reduce these peak flow rates.

Investigations proceeded toward achieving the desired protection using channel improvements and sediment basins. The steep slopes produce high velocity flow; therefore, unlined channels also were eliminated from consideration in this project.

Eight sediment basins, three lined channels to the sea and two lined floodwater diversions to debris basins will be included in the structural measures (see Project Map).

The three sediment basins with lined channels to the sea will reduce the volume of sediment being carried to the ocean as well as reduce flooding. These are located in the Napili 2-3, Mahinahina and Honokowai areas. These basins have no flood retarding effect; therefore, the spillways for these structures and the lined channels downstream have been designed to carry the peak flow from the 100-year storm plus freeboard. Channels with a rectangular cross section were found to be the most economical because of the high cost of land.

The five other basins, acting only as sediment reduction structures, are planned for the Napili 4-5, Honokeana, Kaopala, Pohakukaanapali and Kahana gulches (see Project Map). (Napili 2-3 and Napili 4-5 are area names designated on U. S. Geological Survey maps.) Channel improvements were not included with these basins because of a lack of direct benefit to the adjacent area. These areas are zoned for residential and resort use but presently (August 1971) are undeveloped. Flood plains will have to be delineated and development restricted unless channel improvements are included in plans for development in these areas. The Soil Conservation Service may provide technical assistance in the development of a management plan for flood plains under the sponsors' land treatment program.

Debris basin capacities were in most cases restricted by topographic conditions. In some instances, dam heights could have been increased, but the additional benefits were not sufficient to offset the costs.

Two floodwater diversions were necessary to reduce floodwater and sediment damage to the flood plains. Each diversion will outlet upstream of a desilting basin and the desilted floodwaters will be carried to the sea in lined channels. The floodwater diversions sever the sugar cane lands thus placing some hardships on field operations. Also, the diversions and adjacent access road will take about a 30-foot wide strip of land out of production. For these reasons, cooperation between the Soil Conservation Service, the land operators and the State Highway Division will be necessary in determining the final location of the diversions. Final drainage plans for the proposed highway and field layout at the time of construction may affect this location.

An analysis was made for all basin and channel sites. Only those showing immediate need were included in the structural works of improvement. The four major gulches in the northern section of the watershed outlet through undeveloped flood plains into relatively deep coastal waters where discolored water is more rapidly dispersed than in the southern section of the watershed. The discolored water in the northern section does not appreciably affect the coastal waters of the southern section. No structural measures are planned for these gulches due to the lack of direct benefits, but an accelerated land treatment program is planned for the pineapple lands adjacent to these gulches.

WORKS OF IMPROVEMENT TO BE INSTALLED

Land Treatment Measures

Measures to be applied are those needed to control erosion and sedimentation and reduce floodwater runoff.

Measures to be installed on cropland include:

1. Contour farming to reduce erosion and runoff.

2. Irrigation water management to increase efficiency and reduce water and soil losses.

3. Infield diversions to pick up runoff water from areas of concentration and carry it at safe volocity to protected outlets.

4. Grassed waterways to provide safe outlets for infield diversions and runoff from field roads.

5. Conservation cropping systems.

6. Crop residue management.

7. Establishment of permanent or temporary vegetative cover whenever cropland is removed from production.

On grassland these practices will be applied:

1. Pasture management including proper use of forage to maintain or improve stands of the desirable forage species, provide soil protection and reduce runoff.

2. Pasture planting to improve or replace poor and low-producing stands.

3. Pipeline for livestock to be installed for efficient and uniform grazing pattern to reduce erosion and runoff.

Forestry measures will include:

1. Proper livestock management on all grazed forest lands to protect soil and reduce runoff.

2. Revegetation with grass or woody vegetation in areas where vegetative cover has been destroyed.

3. Reforestation of barren slopes in the lower portion of the watershed will provide soil protection, reduce runoff, and enhance scenic, recreation, and wildlife habitat.

Structural Measures

Structural measures will supplement the land treatment program in reducing floodwater and sediment damages. Tables 1 and 2 list the cost distribution of the proposed measures by types and by individual structure systems, respectively. Tables 3 and 3A list the design features of the various structural measures. Figures 4 through 8 show plan, profile and cross sections of the channel structures and details of the desilting basins. The structure locations are shown on the Project Map.

Each debris basin will be designed with a single spillway structure. All eight spillways will be designed for the 100-year peak runoff plus freeboard. Conditions at each site require certain variations in the type of outlet to be used. Napili 2-3 will discharge through a box inlet spillway into a conduit under the embankment and into the lined channel. Mahinahina will discharge through a box inlet spillway into a conduit under the road fill for the new Honoapiilani Highway and into the lined channel. Honokowai will discharge through a box inlet spillway with a chute down the embankment and transition into the lined channel. Pohakukaanapali will discharge through a box inlet spillway into a culvert under the new highway with an energy dissipator structure at the outlet; the downstream channel will not be improved. The other basins all will discharge through a box inlet spillway with a chute down the embankment and an energy dissipator structure at the bottom; these downstream channels also will not be improved. Drawings of these structures are shown in Figures 4 through 8.

The debris basins will be created by constructing small earth dams. Maximum height of dam will be 43 feet. (See Table 3A.) Two of these dams, Mahinahina and Pohakukaanapali, will be designed and built in conjunction with the fill across these gulches for the new Honoapiilani Highway. Earth fill will consist of local sandy silt materials available at each site. Laboratory tests show this material is suitable for this purpose. The top width of the road fills will be about 120 feet wide and will be compacted according to ASSHO standards. The culverts will be of corrugated metal pipe and will be replaced once during the life of the project.

None of these basins have a significant reservoir capacity and must be cleaned of trapped sediment after each major storm or at least annually.

Approximately 3,900 feet of reinforced concrete channels will be constructed in the Napili 2-3, Mahinahina and Honokowai streams. Due to high velocity flows the channels will be fenced for public safety. Concrete-lined floodwater diversions approximately 4,290 feet in length will divert flows from the sugar cane fields into Honokowai and Mahinahina gulches. Flows will be supercritical, reducing sediment accumulation and clean out costs.

The channels and floodwater diversions will be excavated through sandy silt surface materials (ML in the Unified Soil Classification System) and into saprolite in the deeper sections. Channel excavation may encounter scattered large boulders and rocky formations at the coastline.

The open channels were designed to control flood flows and prevent flooding in the lower sections of the watershed. The design capacities are based on storm runoff for the one percent chance of occurrence.

SCS PHOTO 4-900-3

This lined channel in Naalehu watershed, island of Hawaii, is typical of the channels proposed for preventing floods in the Honolua watershed.

New bridges will be constructed and eight-inch watermains relocated at the highway crossings of the Napili 2-3, Mahinahina and Honokowai channels. A bridge will also be constructed at the cane haul road and Honokowai channel crossing. Three culverts will be installed and irrigation pipes relocated along the Honokowai Floodwater Diversion.

EXPLANATION OF INSTALLATION COSTS

Land Treatment Measures

The estimated costs for installing land treatment measures are shown in Table 1. These are estimates of total costs for establishing prescribed measures over the five-year installation period. Estimated total cost is $361,180. This includes $251,430 to be borne by land owners and operators in applying the needed measures. The remaining $109,750 provides for technical assistance by the Soil Conservation Service and Forest Service to land owners and operators in the watershed. The PL-566 share of the remaining cost, estimated at $77,100, will cover expenses for furnishing technical assistance at an accelerated rate to meet the five-year schedule. Other costs estimated at $31,350 cover Soil Conservation Service, Forest Service and State Forestry Division costs for the normal on-going programs. In addition, other costs estimated at $1,300 cover technical assistance at an accelerated rate by the State Forestry Division.

Cost estimates for installing land treatment measures, including technical assistance, are calculated from current cost figures and past experience in applying similar measures in the state.

The standard soil survey of Honolua watershed has been completed by the Soil Conservation Service. No project costs are anticipated for obtaining additional soil survey information.

Structural Measures

The installation costs for structural measures are shown in Tables 1 and 2. These costs include estimates of all expenditures to be incurred for construction, engineering services, project administration and land rights required for installation of the structural measures.

The structures were separated into the various elements of construction and unit prices paid for similar elements of work on recent projects were used to estimate total construction costs. These estimated costs were increased by 15 percent for contingencies. The total construction cost for flood prevention is $2,574,610 and will be borne by PL-566 funds.

Cost of the road fills and culverts in the Mahinahina and Pohakukaanapali gulches is not included in the project cost. Replacement cost of the culverts is included in the

operation and maintenance costs (Table 4) and will be borne by other funds.

Engineering costs include those for engineering and geologic investigations, surveys, structural design and related activites. Estimated PL-566 cost is $328,950 with no cost to other funds.

Land rights costs include all expenditures for the acquisition of land, easements, and rights-of-way; for necessary construction of bridges; and for relocation of roads and utilities. Land rights costs were estimated after consulting with realtors on Maui and Oahu who are actively handling land transactions in and near the watershed. Bridge construction and other costs were based on past PL-566 and similar projects.

Total land rights cost is estimated at $687,310 and will be borne by other funds. Of this $213,080 is for bridge and culvert construction, $6,100 for relocation of watermains at the Napili 2-3, Mahinahina and Honokowai channel and highway crossings, $36,100 for channel fencing and $3,000 for relocation of irrigation pipes across the Honokowai Floodwater Diversion.

Project administration costs include expenditures for contract administration, construction surveys, review of engineering plans prepared by others, and construction inspection services. Estimated PL-566 cost is $257,460 and other funds cost is $110,000.

The estimated funds needed for installation of the project are tabulated below:

Fiscal Year	Activity	Funds (Dollars)		
		PL-566	Other	Total
First	Land treatment	13,840	61,840	75,680
	Structural	108,630	128,900	237,530
Second	Land treatment	14,540	56,090	70,630
	Structural	581,290	469,460	1,050,750
Third	Land treatment	16,240	56,070	72,310
	Structural	1,405,500	93,910	1,499,410
Fourth	Land treatment	17,040	54,110	71,150
	Structural	400,280	61,600	461,880
Fifth	Land treatment	15,440	55,970	71,410
	Structural	665,320	43,440	708,760
Total Land Treatment		77,100	284,080	361,180
Total Structural		3,161,020	797,310	3,958,330
TOTAL PROJECT COST		3,238,120	1,081,390	4,319,510

EFFECTS OF WORKS OF IMPROVEMENT

The proposed land treatment and structural measures are designed to complement each other and provide an integrated approach to reduce flood runoff and erosion that causes siltation and sediment pollution of beaches and coastal waters. These measures will promote and stabilize agricultural developments and protect the homes, businesses and lives of the people of Honolua watershed.

Use of crop residue, contour farming, conservation cropping systems and grassed waterways on cropland will serve to increase water penetration and reduce erosion. Pasture management on grassland will promote better forage and provide soil protection.

Reforestation will improve the watershed cover and enhance the scenic and recreation values and wildlife habitats. On lands suitable for commercial forest, tree crops will be considered as economic enterprises and thus aid in expanding the economic base of the watershed.

Based on land treatment efficiency rates of 65 to 75 per cent reduction in erosion experienced by practices in Napili subwatershed, proposed treatment measures will reduce average annual floodwater, sediment and erosion damages to agricultural areas considerably. These areas, consisting of pineapple, sugarcane and pasture lands are located above proposed structural measures.

Land treatment measures will also reduce floodwater, sediment and erosion damages to residential, commercial and public facilities by approximately 5 per cent.

In addition, treatment measures will reduce annual damages caused by sediment pollution of watershed coastal areas. Although unmeasurable in terms of dollars, these practices will enhance the environmental amenities of the watershed. Furthermore, reduction of sediment pollution will enhance coral reef development and improve the capability of shore areas to support a larger fish population.

The proposed water disposal systems of floodwater diversions and stream channel improvements are designed to contain the runoff from storms up to and including the 100-year frequency of occurrence. Project measures will provide flood plain residents with protection from floodwater damages. Agricultural lands and resort-commercial developments will also be protected. Considerable savings will result from reduced county expenditures for highway maintenance and repair.

The sediment basins will trap an estimated 72 per cent of the sediment transported from the watershed and thus reduce siltation and sediment pollution to a four-mile ocean-front of the watershed.

The area benefited by proposed structural measures encompasses approximately 80 acres. Included in this area are 2 businesses, 126 residences and 20 resort-apartment hotel developments.

Average annual secondary benefits will accrue within the immediate zone of influence. These benefits relate directly to the increase and stabilization of transporting, processing and marketing of goods and services stemming from the project.

The project will not impose any detrimental effects on present sources of water or existing distribution systems. Proposed land treatment measures will reduce damage to existing irrigation systems.

Structural works of improvements are not expected to adversely affect fish and wildlife habitat. Lower reaches of improved channels extending below sea level will provide stillwater areas reaching inland from the coastline. These areas should provide excellent habitat for various marine life that thrive in brackish water.

PROJECT BENEFITS

Total average annual flood damage was estimated at $413,310. Installation of project measures will reduce damage to $50,510. The difference of $362,800 in flood damage reduction benefits is attributed to proposed land treatment amounting to $25,310 and structural measures amounting to $337,490. (See Tables 5 and 6).

Land treatment measures of the proposed accelerated program will reduce annual floodplain damage by approximately $25,310. Flood prevention structural measures will provide annual benefits amounting to $370,660. This includes primary benefits of $337,490 and secondary benefits of $33,170. Secondary benefits from a national viewpoint were not considered in the economic evaluation of the project.

Proposed land treatment measures will also reduce average annual floodwater, sediment and erosion damages to agricultural areas located above the proposed structural measures by $16,770.

Unevaluated project benefits are improved aesthetic conditions and, most important, protection of human life.

COMPARISON OF BENEFITS AND COSTS

Average annual benefits accruing to structural measures are estimated at $370,660. Average annual cost of these measures is $243,190. The ratio of benefits to costs is 1.5:1.0 including local secondary benefits.

The benefit to cost ratio without inclusion of secondary benefits is 1.4:1.0.

Benefits and cost for project flood prevention measures are shown in Table 6.

PROJECT INSTALLATION

The execution of this plan will be a joint undertaking of private, local government and federal interests. Land treatment measures on private and state lands will be installed by individual land operators or owners cooperating with the West Maui Soil and Water Conservation District with technical assistance given by the Soil Conservation Service. Technical assistance on forest land treatment measures will be provided by the State Division of Forestry in cooperation with the Forest Service.

The structural measures will be installed by the County of Maui with assistance by the Soil Conservation Service.

The sponsoring local organizations and the Soil Conservation Service have agreed to the following specific responsibilities for the project installation:

The West Maui Soil and Water Conservation District will:

1. Provide local leadership and direction to continue the going conservation program of the District.

2. Provide local leadership to insure the scheduled installation of the accelerated land treatment program on private lands.

The District will give first priority to planned land treatment work in the watershed during the installation period. The District will stress planning and application of land treatment through special meetings and personal contacts.

The County of Maui will:

1. Survey, acquire and record all necessary land, easements and rights-of-way for the structural measures.

2. Act as contracting local organization for the construction of the structural measures. If, during the installation period, federal administration of contracts is desired, the County of Maui will make necessary arrangements with the Soil Conservation Service.

3. Obtain the necessary permits for surveys and investigations required for design purposes.

4. Design and install all bridges or road crossings required on county or private roads for the structural measures. Coordinate the installation of state highway crossings. Maintain or provide for maintenance of these structures.

5. Provide for the installation, operation and maintenance of all structural measures.

6. Furnish the non-federal share for other project administration costs.

Prior to the release of invitations to bid, project agreements will be executed between the sponsors and the Soil Conservation Service. These agreements will cover all commitments of responsibilities of all parties, including but not limited to, those items pertaining to financing, inspection and maintenance. Full conformance with state and federal laws and regulations will be the responsibility of non-federal interests.

The County of Maui has the power of eminent domain, can form improvement districts and assess taxes for the improvements, can receive gifts and contributions and can issue bonds for county improvements. The required land, easements and rights-of-way will be acquired by negotiation or, if necessary, by exercising the right of eminent domain. With the sponsor's agreement to use such powers, P. L. 566 assistance for construction may be provided when a court order has been issued for the transfer of lands.

The sponsoring local organizations have given the Soil Conservation Service adequate assurance that their share of project costs will be available as required and that acquisition of land rights for the first two years of construction will commence as soon as possible.

<u>The Soil Conservation Service will</u>:

1. Furnish necessary technical assistance through the West Maui Soil and Water Conservation District to landowners for installing land treatment measures.

2. Furnish the necessary engineering survey and design services for all the structural measures.

3. Furnish the necessary project administration services to assure that installation of structural works will conform to acceptable standards.

4. Allot construction money to the project in accordance with the time schedule set forth herein, or as revised by mutual agreement and in accordance with national priorities and availability of appropriations at the time of installation.

5. Maintain liaison with the sponsoring local organizations, state and other federal agencies involved in the project to the end that unified efforts and coordinated action will produce the most effective results.

6. Consult with and assist the sponsoring local organizations in making desired revisions of the plan.

The schedule for installation of structural measures follows:

SCHEDULE FOR INSTALLATION OF STRUCTURAL MEASURES

Structure		Item	Fiscal Year				
Location	Number		First	Second	Third	Fourth	Fifth
Napili 2-3 Napili 4-5	1 2	Design Land Acquisition Construction					
Honokowai	8	Design Land Acquisition Construction					
Mahinahina Pohakukaanapali	7 6	Design Land Acquisition Construction					
Honokeana Kaopala	3 4	Design Land Acquisition Construction					
Kahana	5	Design Land Acquisition Construction					

Note: Construction time shown includes time for advertising bids and awarding contract.

Other state and federal agencies, by agreement with the sponsors, will participate as follows:

The U. S. Forest Service will:

Cooperate with the State Forester in providing tree planting stock and furnishing technical assistance for land treatment on all non-federal forest land.

The Board of Land and Natural Resources will:

1. Through its Division of Water and Land Development, assist the sponsors as needed to accomplish the work plan.

2. Through its Division of Forestry, in cooperation with the U. S. Forest Service, provide technical assistance in reforestation practices in the 16,650 acres of state and privately owned forest land.

The Agricultural Stabilization and Conservation Service Committee, State and County, will:

Give high priority to scheduling Rural Environmental Assistance Program (REAP) funds to expedite the land treatment measures on private lands.

FINANCING PROJECT INSTALLATION

Land Treatment Measures

The cost of installing land treatment measures on cultivated and forested lands, both private and state, will be borne by land owners and operators. Accelerated cost-sharing assistance to farmers may be available through the U.S.D.A. Rural Environmental Assistance Program.

Technical assistance will be provided by the Soil Conservation Service and the State Division of Forestry with going program funds. Additional P. L. 566 funds will be available to the Soil Conservation Service and the Forest Service to implement the plan for accelerated technical assistance.

Structural Measures

The County of Maui, under the Hawaii Revised Statutes, 1968, has authority to carry out, maintain and operate flood control projects. Funds needed to carry out its obligations, as defined in this work plan and agreed to in the Watershed Work Plan Agreement, can be provided through the Maui County Capital Improvement Projects budget. The sponsors do not propose to use loan provisions of the Watershed Protection and Flood Prevention Act.

Federal assistance for carrying out works of improvement will be provided by the authority of Public Law 566 (Watershed Protection and Flood Prevention Act, 83rd Congress; 68 Stat. 666, as amended). Financial and technical assistance furnished by the federal government is contingent on appropriation of funds for these purposes.

PROVISIONS FOR OPERATION AND MAINTENANCE

Land Treatment Measures

Land treatment measures will be maintained by the owners or operators of the lands on which the measures are installed. Technical assistance for the maintenance of the measures will be provided by the Soil Conservation Service through the West Maui Soil and Water Conservation District and by the State Division of Forestry.

Structural Measures

The operation and maintenance of all structural measures will be the responsibility of the County of Maui. An operation and maintenance agreement will be executed between the County of Maui and the Soil Conservation Service prior to signing the project agreements.

The County of Maui will be responsible for obtaining rights-of-entry or other instruments, where needed, to allow access to the easements or rights-of-way of the structures. Access to these areas will be solely for operation and maintenance functions and for inspection of the structures.

The maintenance program will include the preservation of the design capacities of channels, desilting basins and other structural components for flood prevention. Debris and unwanted vegetative growth will be removed from the structural measures periodically. Sediment deposited in the desilting basins will be cleaned out after major storms or at least annually. It is estimated that an average of over 12,000 cubic yards will be removed each year.

Some damage to the structures during infrequent events may occur. Cost for repair of damage will be considered to be maintenance costs.

The total estimated annual cost for operation and maintenance is $29,280.

The County of Maui and the Soil Conservation Service will jointly inspect all structures annually, or after severe floods, for three years following installation of each structure. All annual and other inspections after the third year will be made by the County of Maui; and a report will be submitted to the Soil Conservation Service, Wailuku Work Unit, stating corrective measures needed and actions taken.

TABLE 1 - ESTIMATED PROJECT INSTALLATION COSTS

Honolua Watershed, Hawaii

Installation Cost Item	Unit	Number Non-Fed. Land	Cost (Dollars) 1/ Non-Federal Land PL-566	Other	Total
LAND TREATMENT					
Soil Conservation Service					
Cropland	Ac.	5,925	-	81,040	81,040
Grassland	Ac.	1,000	-	119,390	119,390
Miscellaneous Land	Ac.	400	-	6,000	6,000
Technical Assistance			71,900	28,850	100,750
SCS Subtotal		7,325	71,900	235,280	307,180
Forest Service					
Forest Land	Ac.	16,650	-	45,000	45,000
Technical Assistance			5,200	3,800	9,000
FS Subtotal		16,650	5,200	48,800	54,000
TOTAL LAND TREATMENT		23,975	77,100	284,080	361,180
STRUCTURAL MEASURES					
Construction					
Soil Conservation Service					
Channels	Ft.	3,900	796,760	-	796,760
Desilting Basins	No.	8	1,514,540	-	1,514,540
Floodwater Diversions	Ft.	4,290	263,310	-	263,310
Subtotal - Construction			2,574,610	-	2,574,610
Engineering Services					
Soil Conservation Service			328,950	-	328,950
Subtotal - Engineering			328,950	-	328,950
Project Administration					
Soil Conservation Service					
Construction Inspection			79,810	50,000	129,810
Other			177,650	60,000	237,650
Subtotal - Administration			257,460	110,000	367,460
Other Costs					
Land Rights				687,310	687,310
Subtotal - Other				687,310	687,310
TOTAL STRUCTURAL MEASURES			3,161,020	797,310	3,958,330
TOTAL PROJECT			3,238,120	1,081,390	4,319,510
SUMMARY					
Subtotal SCS			3,232,920	1,032,590	4,265,510
Subtotal FS			5,200	48,800	54,000
TOTAL PROJECT			3,238,120	1,081,390	4,319,510

1/ Price base: 1971

TABLE 1A - STATUS OF WATERSHED WORKS OF IMPROVEMENT

Honolua Watershed, Hawaii

Measures	Unit	Applied To Date	Total Cost (Dollars) 1/
LAND TREATMENT			
Conservation Cropping System	Ac.	2,400	12,000
Contour Farming	Ac.	2,400	19,200
Crop Residue Management	Ac.	825	8,250
Grassed Waterway	Ac.	29	18,440
Diversions	Ft.	13,470	2,560
Irrigation Water Management	Ac.	200	640
Pipeline for Livestock	Ft.	5,900	1,770
Brush Control	Ac.	500	11,500
Pasture Management	Ac.	1,900	57,000
Pasture Planting	Ac.	146	8,760
Tree Planting	Ac.	200	40,000
TOTAL			180,120

1/ Price base: 1971

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TABLE 2 - ESTIMATED STRUCTURAL COST DISTRIBUTION

Honolua Watershed, Hawaii

(Dollars) 1/

Item	Installation Cost PL-566 Funds			Installation Cost Other Funds	Total Installation Cost
	Construction	Engineering	Total	Land Rights Total	
Napili 2-3 Channel	181,150	21,740	202,890	88,370	291,260
Mahinahina Channel	152,100	18,250	170,350	51,320	221,670
Honokowai Channel	463,510	55,620	519,130	217,000	736,130
Mahinahina Floodwater Diversion	123,860	14,860	138,720	20,850	159,570
Honokowai Floodwater Diversion	139,450	16,730	156,180	59,860	216,040
Napili 2-3 Desilting Basin	122,650	17,220	139,870	18,000	157,870
Napili 4-5 Desilting Basin	127,290	17,770	145,060	530	145,590
Honokeana Desilting Basin	93,940	13,770	107,710	23,600	131,310
Kaopala Desilting Basin	92,100	13,550	105,650	12,730	118,380
Kahana Desilting Basin	511,820	66,420	578,240	42,880	621,120
Pohakukaanapali Desilting Basin	45,210	5,430	50,640	11,330	61,970
Mahinahina Desilting Basin	84,980	10,200	95,180	24,000	119,180
Honokowai Desilting Basin	436,550	57,390	493,940	116,840	610,780
Subtotal	2,574,610	328,950	2,903,560	687,310 2/	3,590,870
Project Administration	-	-	257,460	110,000	367,460
GRAND TOTAL	2,574,610	328,950	3,161,020	797,310	3,958,330

1/ Price base 1971.

2/ Includes $6,250 for legal and other fees for land acquisition; $6,100 for relocation of watermains at the Napili 2-3, Mahinahina and Honokowai Highway and channel crossings; $213,080 for bridge and culvert construction; $36,100 for channel fencing; and $3,000 for relocation of irrigation pipes across the Honokowai Floodwater Diversion.

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TABLE 3 - STRUCTURE DATA

DESILTING BASINS

Honolua Watershed, Hawaii

Item	Unit	Structure Number 1	2	3	4	5	6	7	8	Total
Class of Structure	-	C	C	C	C	B/C	C	C	B/C	-
Drainage Area	Sq. Mi.	0.43	0.93	0.57	0.94	4.53	0.24	1.90	5.98	15.52
CN (1-Day)(AMC II)	-	71	65	76	62	68	78	68	63	-
Elevation Top of Dam	Ft.	70	59	55	60.5	62	67	55	60	-
Elevation Crest Spillway	Ft.	63	52	49	53	50	62	42	50	-
Drop Distance	Ft.	10	11	10	12	18.3	16	20	16	-
Maximum Height of Dam	Ft.	30	30	24	25	43	25	25	25	-
Volume of Fill	Cu. Yds.	21,210	15,770	10,120	8,000	60,370	-	-	38,470	153,940
Storage Capacity To Spillway Crest	Ac. Ft.	15.6	25	11.5	22	82	3	36	83	278.1
Spillway Capacity										
Freeboard	cfs	1,940	3,250	2,190	3,170	18,760	1,490	7,340	20,150	-
100-year event	cfs	1,030	1,600	1,210	1,330	7,400	645	4,100	8,450	-
Capacity Equivalents										
Sediment Volume	In.	0.68	0.50	0.38	0.44	0.34	0.23	0.36	0.26	-
Retarding Volume	In.	0	0	0	0	0	0	0	0	-

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TABLE 3A - STRUCTURE DATA

CHANNELS

Honolua Watershed, Hawaii

Channel	Station	Drainage Area sq. mile	Capacity cfs		Water Surface Elev. 1/	Invert Slope ft/ft	Channel Dimensions			Velocity fps	Total Excavation cu yds
			Req'd	Design			Bottom ft	Depth ft	Side Slopes		
Napili 2-3 Channel	2+05	0.43	1,030	1,030	32.7	0.0070	10	6.3	0	38.2	-
	7+00	0.43	1,030	1,030	31.0	0.0460	10	5.4	0	22.9	-
	11+25	0.56	1,040	1,040	10.2	0.0070	10	3.8	0	32.2	-
	11+45	0.56	1,140	1,140	10.0	0.0070	10	3.8	0	32.2	-
	17+50	0.58	1,140	1,140	8.2	0.0070	10	6.7	0	20.4	6,976
Mahinahina Channel	2+70	1.90	4,100	4,100	18.3	0.0136	23	11.0	0	32.7	-
	2+85	1.90	4,100	4,100	18.0	0.0136	20	7.9	0	31.1	-
	7+10	1.90	4,100	4,100	12.6	0.0136	20	7.9	0	31.1	-
	10+92	1.94	4,100	4,100	7.4	0.0136	20	7.9	0	31.1	3,323
Honokowai 1/ Channel	1+00	5.98	8,740	8,740	38.4	0.0465	70	14.0	0	15.7	-
	2+70	5.98	8,740	8,740	32.8	0.0150	36	12.0	0	23.5	-
	8+45	6.0	8,740	8,740	21.6	0.0150	36	8.9	0	31.7	-
	16+33	6.0	8,740	8,740	9.1	0.0150	36	8.0	0	35.0	43,260
Mahinahina Floodwater Diversion	0+00	0	0	277	78.0	0.0150	4	2.9	1.5	0	-
	7+50	0.15	277	277	66.7	0.0150	4	2.9	1.5	16.3	-
	15+00	0.22	415	415	55.4	0.0150	4	3.5	1.5	18.1	-
	16+40	0.22	415	415	26.7	0.1970	6	2.1	0	40.7	2,910
Honokowai Floodwater Diversion	0+00	0	0	225	101.7	0.0150	4	2.6	1.5	0	-
	8+00	0.12	225	225	89.7	0.0150	4	2.6	1.5	17.3	-
	24+00	0.24	450	450	65.4	0.0150	4	3.7	1.5	19.3	-
	26+50	0.24	450	450	29.9	0.1380	6	2.3	0	39.5	4,490

Note: "n" value for all concrete-lined channels is 0.014.

1/ Channel improvement from Honoapiilani Highway to ocean will be accomplished by private developer.

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TABLE 4 - ANNUAL COST

Honolua Watershed, Hawaii

(Dollars) 1/

Evaluation Unit	Amortization of Installation Cost 2/	Operation and Maintenance Cost	Total
All Structural Measures	194,050	29,280	223,330
Project Administration	19,860	-	19,860
GRAND TOTAL	213,910	29,280	243,190

1/ Price base: Installation 1971, O&M adjusted normalized.
2/ 100 years at 5-3/8 percent interest.

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TABLE 5 - ESTIMATED AVERAGE ANNUAL FLOOD DAMAGE REDUCTION BENEFITS

Honolua Watershed, Hawaii

(Dollars) 1/

Item	Estimated Average Annual Damage		Damage Reduction Benefit
	Without Project	With Project	
Floodwater			
Agricultural	5,290	-	5,290
Resort-Commercial	92,870	-	92,870
Residential	28,060	1,200	26,860
Public Agencies and Utilities	510	200	310
Subtotal	126,730	1,400	125,330
Sediment			
Agricultural	4,860	-	4,860
Resort-Commercial	198,060	40,460	157,600
Residential	9,220	-	9,220
Public Agencies and Utilities	2,770	-	2,770
Subtotal	214,910	40,460	174,450
Erosion			
Flood Plain Scour	3,980	-	3,980
Subtotal	3,980	-	3,980
Indirect	67,690	8,650	59,040
TOTAL	413,310	50,510	362,800

1/ Normalized price base. Damages and benefits will accrue from floods of greater magnitude than 1% frequency but were not evaluated.

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TABLE 6 - COMPARISON OF BENEFITS AND COSTS FOR STRUCTURAL MEASURES

Honolua Watershed, Hawaii

(Dollars)

Evaluation Unit	AVERAGE ANNUAL BENEFITS 1/		Total	Average Annual Cost 3/	Benefit Cost Ratio
	Damage Reduction 2/	Secondary			
All Structural Measures	337,490	33,170	370,660	223,330	1.7:1.0
Project Administration	-	-	-	19,860	-
GRAND TOTAL	337,490	33,170	370,660	243,190	1.5:1.0

1/ Normalized price base.
2/ In addition, it is estimated that land treatment measures will provide floodwater, sediment and erosion damage reduction benefits of $25,310 annually.
3/ Table 4.

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INVESTIGATIONS AND ANALYSES

Project Formulation

Land Treatment Measures

Land treatment measures to be applied in the watershed area are the needed treatment measures as determined by the Soil Conservation Service, the Hawaii Division of Forestry, the U. S. Forest Service, and the local sponsors. Soil survey maps prepared by SCS and field maps obtained from the land operators form the base on which the treatment needs were determined. These needs conform to the standards and specifications for practices as set forth in the Technical Guide prepared for use in the West Maui Soil and Water Conservation District.

Survey and analysis of the forested and brush covered portions of the watershed was accomplished by cooperative effort between the Hawaii Division of Forestry and the U. S. Forest Service. Land treatment recommendations are based upon results obtained through research and application of land treatment measures installed on similar watersheds.

Structural Measures

Floodwater retarding reservoirs for controlling flood flows were investigated. Lack of feasible sites, due to the steep terrain, eliminated possibilities for detention storage. Channel improvements were determined to be the most feasible measures for flood prevention.

Desilting basins, in conjunction with land treatment measures, were determined to be the most effective way to reduce sediment deposition in the flood plains and coastal waters. Height of the dams, which range from 24 to 43 feet, was limited in most cases by topographic conditions. In some instances dam heights could have been increased, but the additional benefits were not sufficient to offset the costs.

Channel and basin designs conform to current SCS engineering criteria. Alignments of needed channel improvements follow the existing drainageways except where other alignments provide shorter and more economical routes. Various channel types were studied for each reach, including unlined and reinforced concrete-lined channels of rectangular and trapezoidal sections. The alternative with the most economical annual cost was always used.

Surveys

Topographic surveys were made in areas where maps were not sufficiently accurate. This survey covered the Mahinahina and Honokowai channel areas. Maps were prepared to a scale of one inch equal to one hundred feet and a contour interval of five feet. Two topographic surveys from aerial photos were also used. One had a scale of one inch equal to one hundred feet and a contour interval of five feet. This survey covered the area between Napili 2-3 and Kaopala. The other had a scale of one inch equal to four hundred feet and a contour interval of twenty feet. This survey covered all the areas where structural and land treatment measures are proposed.

Hydrology

Basic Data

Two crest-stage and one water-stage recorder for measuring stream flows are located within the watershed. Another water-stage recorder is located east and adjacent to the project area. The crest-stage gauges were installed in 1963 at Honokeana Stream and in 1965 at Honokowai Stream. These are located well downstream and measure almost all the runoff from these two watershed areas. The water-stage recorders are installed at Honokohau and Kahakuloa streams and have 51 years and 24 years of flood flow record, respectively. They are located near the headwater of the streams and measure runoff from forest lands. Records of these gauges are published in the U. S. Geological Survey Progress Report, "An Investigation of Floods in Hawaii."

Several rain gauges have been installed within the project area. Five are presently in operation. Of these, two are recording, two are read daily and one is read weekly. One of the recording, the two daily and the weekly gauges are official gauges. Their records are published in U. S. Weather Bureau publications.

These stream gauge and rain gauge records, together with soil survey maps, land use maps and data from field surveys of ground cover conditions, were used in estimating the hydrologic characteristics of the watershed.

Design Flow Rates

Peak flow rates were calculated using the procedures contained in Chapter 21 of SCS National Engineering Handbook, Section 4, Hydrology.

Rainfall amounts for the 100-year event were taken from U. S. Weather Bureau, Technical Paper No. 43, "Rainfall Atlas of the Hawaiian Islands."

Watershed characteristics used to develop volumes and peak rates of runoff include curve numbers (CN) and times of concentration (Tc). These were estimated using procedures described in Chapters 7, 8 and 9, NEH-4. Antecedent moisture condition II was used for all runoff calculations. Times of concentration were estimated using Kirpich's formula,and when expressed in velocities of travel, were found to be reasonable.

As a check on the method of hydrograph synthesis, two flood events were analyzed. Peak flow rates were computed using the method and were found to compare favorably with the measured rates.

As a comparison, frequency analyses were made for the annual flood peaks of Honokahau and Kahakuloa streams using the log-Pearson Type III distribution. Data was plotted according to Hazen's frequency plotting positions. From the analyses, a curve of drainage area versus peak flow rates was developed. Peak rates estimated from this curve were slightly lower than the computed design flow rates.

Freeboard

Freeboard hydrographs for the debris basins were computed using the same method and watershed characteristics used in the design flow rates computation. Rainfall amounts used to develop the freeboard hydrograph for structures 1, 2, 3, 4, 6 and 7 were computed using the formula, $P_{100} + .40\ (PMP - P_{100})$, where P_{100} is the six-hour, 100-year rainfall and PMP is the six-hour probable maximum rainfall. Rainfall amounts for structures 5 and 8 were the average six-hour precipitation for developing freeboard hydrographs for class b and class c structures.

Rainfall values are taken from Technical Paper No. 43 of the Weather Bureau and SCS National Engineering Handbook, Section A.

Storm Frequencies

Flood frequencies of recent flood events were estimated using the depth-duration-frequency curves and U. S. Weather Bureau Technical Paper No. 43. These frequencies were used in the economic investigations and analysis for both floodwater and sediment damages. Additional data for floodwater damage analyses in the Napili 2-3 flood plain were obtained by routing the computed flow rates of the 100-year, 50-year and 10-year storm events.

Hydraulic and Structural Design

Desilting Basins

Concrete and concrete-lined earth dams, allowing weir flow over their entire length, were investigated. An advantage of this design feature is the large freeboard flows that can be discharged. However, earth fill dams, as shown in figures 4 through 8, were less costly. The spillways are designed to discharge the freeboard hydrograph which is more economical than providing a separate emergency spillway. Upstream and downstream slopes will be grassed to prevent erosion.

Costs were determined for various spillway structures. Drop spillways, box inlet spillways, flip bucket spillways, straight inlets and other designs were investigated. The box inlet spillway was the least costly.

An ungated trickle tube with a graded gravel filter inlet and a rectangular concrete riser running up the slope of the dam will drain the basin. The riser will be provided with removable flash boards in order to drain the basin when the gravel filter system becomes clogged and in need of maintenance.

The box inlet spillway designs were based on "Rounded-Rectangular Weir Box Inlets" in the NEH 14, _Chute Spillways_; Agricultural Handbook No. 301, _Hydraulic Design of the Box-Inlet Drop Spillway_; and NEH 6, _Structural Design_.

The energy dissipating structures were designed using criteria based on the NEH 14, _Chute Spillways_.

Trap efficiencies of the desilting basins were based on the paper "_Efficiency of Reservoirs_," _Transactions_, American Geophysical Union, June 1953. The center curve of the three-curve graph using the storage capacity-annual inflow ratio was used. This is believed to be conservative due to the highly flocculated soils.

Channels

Channel hydraulic design was based on the NEH 5, _Hydraulics_ and SCS _Engineering Design Standards - Far West States_. A Manning's "n" value of 0.014 was used for the concrete lining. Water surface profiles were computed from the inlet downstream.

The channels flowing from the basins to the sea and the floodwater diversion channels intercepting sugar cane field runoff and discharging into Mahinahina and Honokowai desilting basins will be flowing at supercritical velocity. With these velocities, concrete lining will be required.

Unlined floodwater diversion channels, on a mild slope, were considered. Design flows would be non-scouring and yet keep sediment from depositing. However, flows entering the channels would create a serious erosion problem. Also, sediment deposition during lesser flows would require continued maintenance. Therefore, concrete-lined trapezoidal channels on steeper slopes were chosen. The outlets will include a rectangular chute into the basin and a small energy dissipating structure.

Rectangular cross sections for the channels to the sea were the most economical due mainly to high land costs.

Geology

Desilting Basins and Borrow Sites

The desilting basins are located in the gulches that separate cultivated fields of pineapple and sugar cane. Preliminary geologic investigations indicate that the foundation and abutment material is highly weathered basalt. This material was pulverized with a rubber mallet and laboratory tested. It was classified as a silt with a low liquid limit (ML).

Road fills and one dry dam about 30 feet high have been constructed near the proposed dam sites with no visual foundation or seepage problems, and none are anticipated in the planned structures.

The borrow areas will be located in the gulches upstream from the dam sites. Borrow material will be excavated to a depth of about 5 to 10 feet and adequate volumes are available. Shear and permeability tests indicate that these materials are suitable for the compacted fill; however, further testing of borings and samples from borrow and dam sites will be necessary for the final design. The cost of detailed investigations is included in this plan.

Alternate dam sites with favorable geologic conditions are numerous. The sites chosen, however, are located as far downstream as possible to intercept flows from the greatest acreage.

Sedimentation

Field examination of the watershed indicates that an appreciable amount of sediment comes from the cultivated lands. Three catchment areas or desilting basins have been installed in the Napili 2-3 subwatershed. These basins have potential sediment pools only 4 to 6 feet deep; however, there has been a marked reduction in the duration of redwaters in the bay according to local residents and businessmen. The planned desilting basins will have a much greater storage capacity than the existing catchments and, therefore, a greater trap efficiency.

Sediment yields were determined from field examination and studies made by the U. S. Geological Survey on the island of Oahu. The USGS has installed sediment gauging stations in conjunction with stream flow recording gauges on some streams on Oahu. They have also taken samples periodically from other streams. With this information

preliminary sediment yields have been determined for various watersheds. Yields ranged from 0.5 to 1.5 acre feet per square mile per year. Undisturbed land produces significantly less sediment than disturbed land. Therefore, sediment yield rates were determined separately for the cultivated lands and the forest lands in the Honolua watershed.

The average annual sediment yield was the basis for determining desilting basin clean out costs.

Channel Sites

No foundation problems are anticipated in channel construction. Subsoil in the channel areas is weathered basalt.

Economics

Framework of Analysis

The initial phase of the investigation consisted of locating, defining and measuring significant watershed problems. Past damage reports reveal that shoreline sediment pollution is a major problem associated with flooding. Therefore, one phase of the investigation was directed to this problem.

Flood and sediment pollution damages were evaluated to determine benefits that would be obtained by land treatment and structural measures. Investigation showed a definite relationship between such elements as depth, area, seasonal occurrence, location and frequency of flooding.

The interrelation of flood prevention and sediment abatement structures was considered. Other factors considered in the selection of evaluation units were present policy and legal restrictions. Existing trends of agricultural operations and urban development were also analyzed in terms of their probable economic impact upon the future economy of the watershed. Land use within the watershed was analyzed to determine the effect of the project on future land use patterns and damages.

The future increase in flood plain damages was also based on the projected increase in per capita personal income and personal consumption expenditures. This evaluation concept is based on the premise that future flood damage rates to urban properties will increase at about the same rate as those projected for personal income. The factor for estimating the increase in residential and commercial damages within the Hawaii Resource Planning Area was based on personal income projections by OBE-ERS.

Damage Appraisal

Appraisal of sediment pollution along the watershed shoreline required collecting data covering major drainage areas that contribute to the pollution problem. The flood plain reaches and oceanfront areas and contributing streams were identified to provide a means for:

1. Identifying and locating damages and benefits.

2. Relating damage reductions and benefits to works of improvement.

3. Relating economic and hydrologic data.

Damage estimates--based on information obtained in the field--were analyzed and correlated with data developed by other specialists. Damage estimates were normalized using the U. S. Department of Commerce Construction Costs Composite Index (1957-59 = 100) and B.L.S. Wholesale Price (all commodities 1957-59 = 100) wherever applicable.

Existing Conditions

Floodwater Damage Analysis

Nine post-flood damage surveys, conducted by the Soil Conservation Service, were analyzed to evaluate past damages under existing conditions. Damages were classified according to types, i.e., sediment, erosion and floodwater. Data was further analyzed by categorizing damages into residential, commercial, agricultural and public agency.

Damage appraisal in agricultural areas was based on losses to agricultural property, including private roads. Crop damage was determined by estimating loss in net income for major crops affected, using data received from plantations in the watershed.

Damages to nonagricultural property, such as residential and resort-commercial, were also determined. Information on damages to highways, bridges and utilities was obtained by interviewing local public agencies and utility companies.

Floodwater damage appraisals included comparing damages expected to occur without the project with those that would occur after the project is installed. Estimates of future average annual damage under existing conditions were made using damage-frequency curves as discussed in Chapter 3 of the Soil Conservation Service Economics Guide.

Sediment Pollution Damage Analysis

Appraisal of sediment pollution damages and benefits in the watershed initially required locating affected oceanfront areas. Analysis of damage data submitted

from the field, supplemented by post-flood surveys, substantiated damaging effects of pollution on existing developments. These surveys were designed to establish or substantiate damaging effects of pollution, identify damage areas, and determine time durations of pollution caused by 13 storms in the watershed during 1955 through 1968. Pollution surveys conducted in October 1967, March 1968, and September 1969, provided adequate data for various supporting areas of analysis. Sediment damages to residential condominiums and resort hotels were closely associated with flood damages and required segregation to facilitate evaluation.

The basic assumption supporting the damage analysis was that sediment pollution of the watershed shoreline is a function of rainfall and erosion. Erosion is influenced by a number of factors, including amount and intensity of rainfall, length and steepness of watershed lands, system of cropping and land management, and erodibility of watershed soils.

The relationship of sediment pollution to rainfall was determined by analyzing each storm in terms of computed frequency and accompanying number of polluted days. Much of the necessary data had to be gathered by surveys designed to measure and relate economic losses to existing hydrologic conditions.

Damages were determined first by establishing the loss of occupancy experienced by a typical resort development during a 24-hour period of polluted oceanfront; second, by deriving the average monetary loss to a typical hotel unit; and third, by determining the average annual number of polluted days that can be expected in a given polluted drainage area. A reasonable estimate of average annual damages attributable to sediment pollution for a typical resort-hotel development can be derived by incorporating these factors in a general equation as follows:

<u>General Equation</u>

Avg. annual number of sediment pollution days	X	RATE OF LOSS (No. of premature check outs per pollution day)	X	Average weighted price of a room-night in watershed area	=	Dollars damage for a particular plotting point on the damage frequency curve

Sediment pollution damages consist primarily of income lost by resort hotels and apartments located on the watershed coastline. Income loss is caused by guests leaving because of the polluted beach conditions. Other losses associated with reduced occupancy levels are lost wages and associated costs such as increased laundry and transportation expenses.

According to resort hotel managers, seasonal rainstorms are usually accompanied by a temporary drop in hotel occupancy. Rainfall and occupancy records were analyzed to determine a relationship. Results indicated that both factors are influenced by other considerations. In some cases, high rainfall periods occur when the tourist season is normally at its lowest level. Therefore, each rainstorm was analyzed individually to determine its true effect upon hotel occupany rates. Storm damage reports were used during this stage of analysis. Other supporting documents such as newspaper accounts supplied additional data. Final analysis indicated that watershed rainstorms can account for approximately 2 to 5 percent reduction of gross annual income for the hotels depending on the location and prevailing hydrologic conditions.

The storm of March 1968 provided data that served as an analytical control point for pollution intensity and duration with which past storms in the watershed could be measured. This storm was estimated to be an 8 percent event and was concentrated in the Honokowai, Mahinahina and Kahana subwatershed areas.

A sediment pollution-frequency curve was developed from surveys and damage reports to further relate the relationship of sediment pollution to rainfall. In effect, this gave each shoreline area affected by pollution its own sediment pollution-frequency curve. Using the curve, the damaging effect of any rainstorm with an assigned frequency could be expressed in number of sediment pollution days. For example, a 22 percent rainstorm in the Napili drainage area would produce approximately 15 days of pollution in Napili Bay and its surrounding shoreline. The average annual pollution days of Napili were thereby calculated. The same procedure was developed for Mahinahina-Kahana-Honokowai shoreline area.

Projected Conditions

Projected floodwater and sediment pollution damages and benefits in the watershed were determined by analyzing and establishing trends of development. During the work plan investigation, the Maui County Planning Commission prepared the General Plan for Lahaina District which includes the Honolua watershed project area. Completed in December 1968, the report was financed in part through an urban planning grant from the Department of Housing and Urban Development, under the provisions of Section 701 of the Housing Act of 1954, as amended.

The Lahaina 701 Plan facilitated the economic investigation and provided a realistic means for estimating future private and public growth within the watershed area and the Lahaina District.

Additional information received from the Maui County Planning Department indicated that the resort facilities programmed for the watershed will achieve full development by 1980. Further analysis of real estate transactions in the watershed indicated that some coastal locations would be fully developed by 1975. Other types of land uses considered in Honolua watershed will attain maximum development within different time periods, and this was taken into consideration in the damage analyses.

Floodwater Damage Analysis

Five segments of the economy in Honolua watershed that were investigated for floodwater damages are: Resort-commercial, residential, public agencies and utilities, commercial and agriculture. Projected urban damages were determined by utilizing proposed land uses contemplated by the general plan and procedures developed by Stanford Research Institute, in their publication, "A Study of Procedure in Estimating Flood Damage to Residential, Commercial and Industrial Properties in California."

The one percent event was synthesized for changed land use conditions in the Napili, Mahinahina and Honokowai flood plains to determine areas and depths of floodwater. Agricultural damage analysis was made with personnel familiar with the watershed.

Sediment Pollution Damage Analysis

Projected damages were based on actual hotel unit densities proposed by the general plan for resort-zoned

lands, and the occupancy loss of the existing hotel industry. It was assumed that the existing rate of occupancy loss would hold true for the projected conditions. The total average annual projected damages for different coastal areas is dependent on their individual rate of development. The analysis also assumes that Honolua watershed will maintain its 1967 share of the total island hotel-room market.

Actual benefits attributable to structural measures is determined by the efficiency of structures to prevent sediment from entering and polluting the oceanfront.

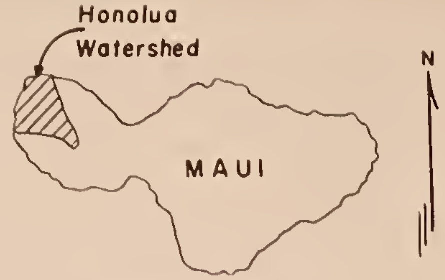
Indirect Damage

The Economics Guide sets forth varying amounts of indirect damages which are permitted without special studies or investigations. The following percentages of indirect to direct damages were used: 10 per cent for agriculture, 15 per cent for urban damages and 20 per cent for sediment pollution damages.

Secondary Benefits

Secondary benefits stemming from installation of the project are profits of local merchants handling increased sales, increased processing and marketing, and the supplying of more goods and services. These benefits were considered to be 10 percent of the direct primary benefits in accordance with Chapter 11 of the Economics Guide.

Benefits induced by the project were considered to be 10 percent of the project operation and maintenance costs, also described in the Economics Guide.



LOCATION MAP

LEGEND

GENTLY SLOPING TO MODERATELY STEEP, WELL-DRAINED, FINE-TEXTURED SOILS. TYPICAL SERIES, HONOLUA AND OLELO.

WELL-DRAINED, MODERATELY FINE TEXTURED REDDISH-BROWN SOILS. TYPICAL SERIES, KAHANA, ALAELOA AND LAHAINA.

ROCK LAND AND VERY SHALLOW SOILS ON STEEP TO EXTREMELY STEEP INTERMEDIATE AND HIGH UPLANDS. (ABOUT 1% OF THIS AREA CONSISTS OF OTHER GENERAL SOILS WHICH ARE NOT DESIGNATED.)

FIGURE 1
GENERAL SOIL MAP
HONOLUA WATERSHED
ISLAND OF MAUI, HAWAII
OCTOBER 1971

2000 0 2000 4000 6000 FEET
SCALE 1:63,360

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
Prepared by S.L.W. Date 12-69 Traced by G.W.S.L.

FIGURE 2
EXISTING LAND USE
HONOLUA WATERSHED
ISLAND OF MAUI, HAWAII
OCTOBER 1971

2000 0 2000 4000 6000 FEET
SCALE 1:63,360

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE
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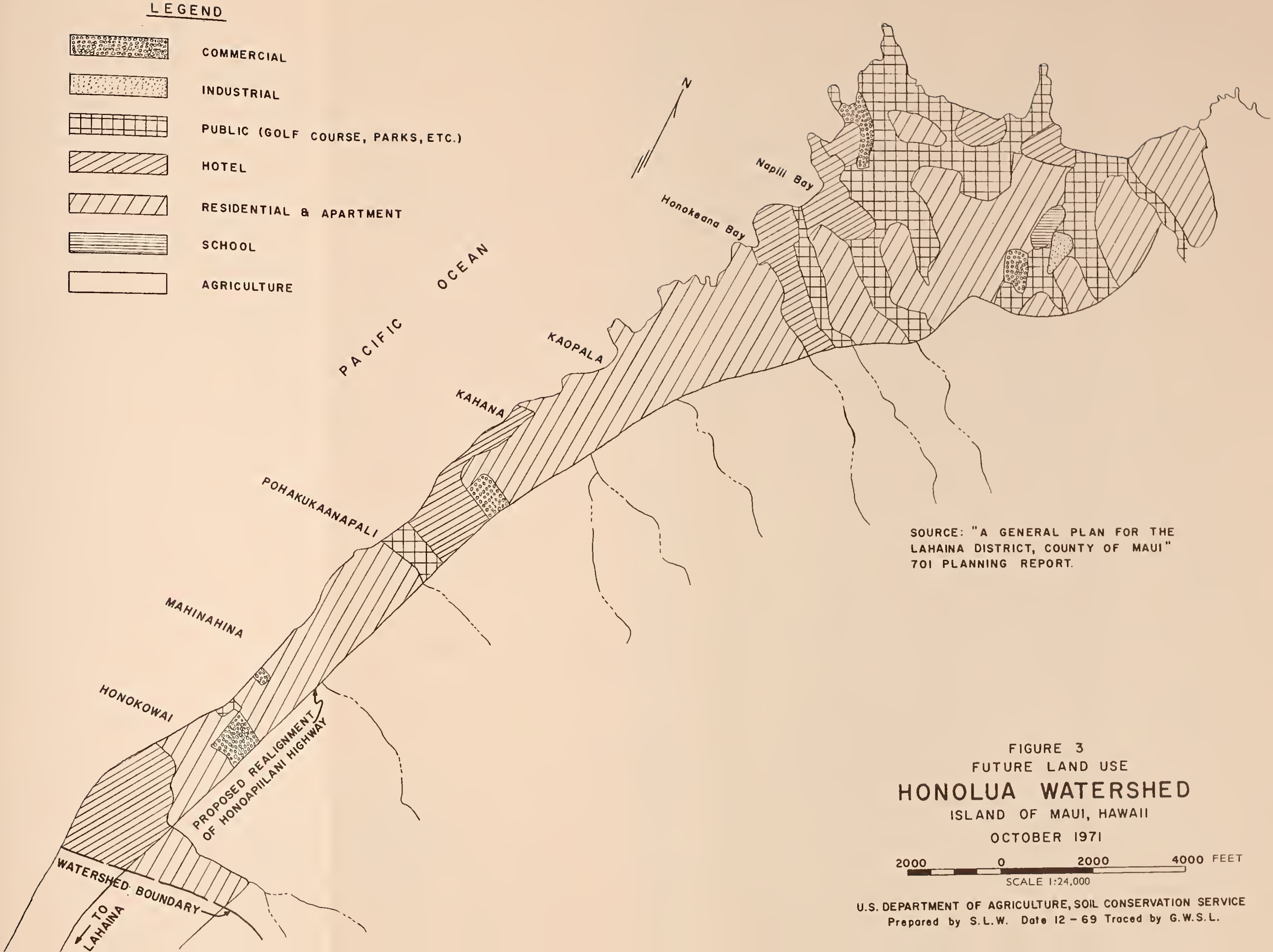

FIGURE 3
FUTURE LAND USE
HONOLUA WATERSHED
ISLAND OF MAUI, HAWAII
OCTOBER 1971

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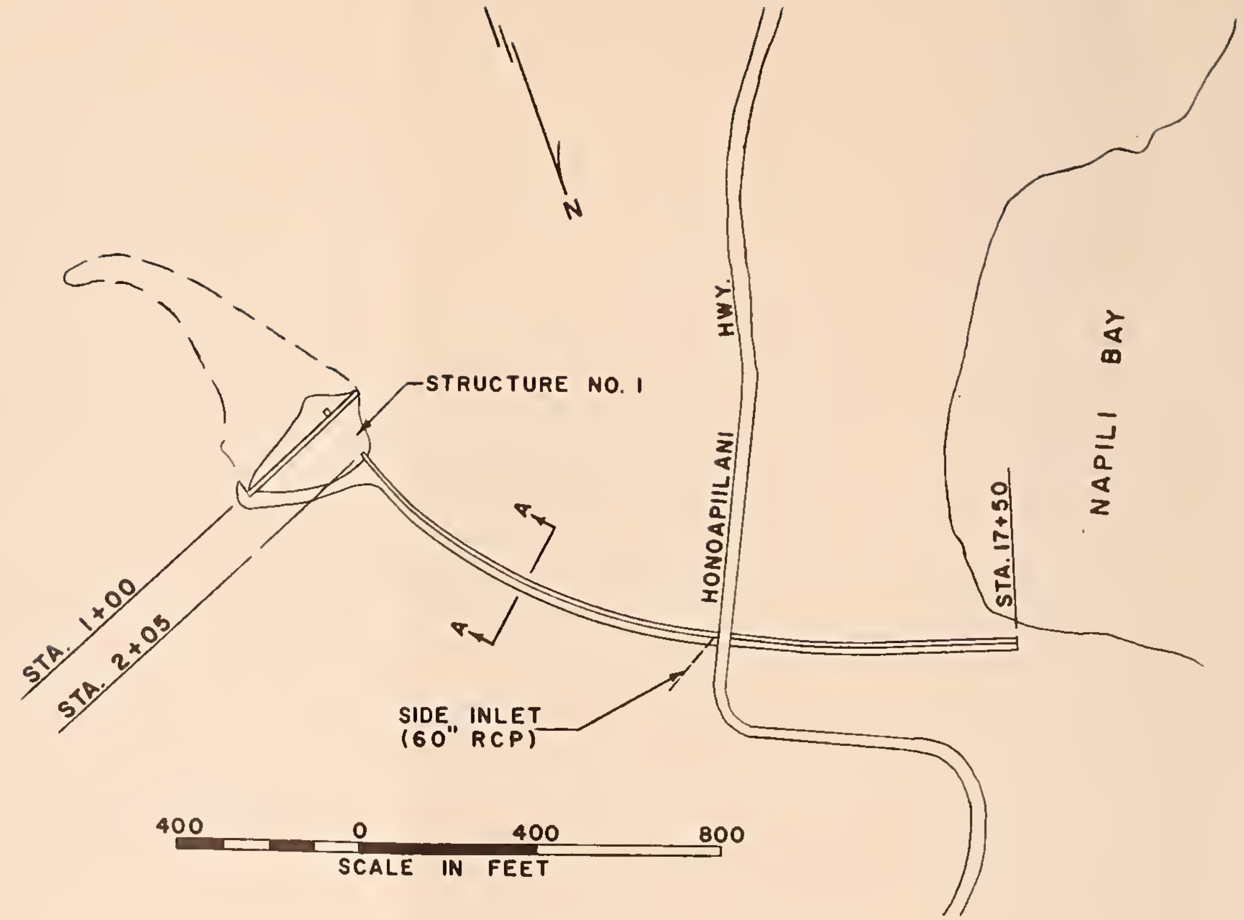
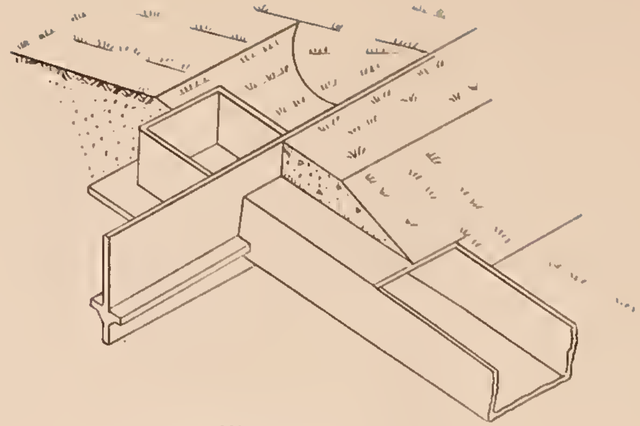
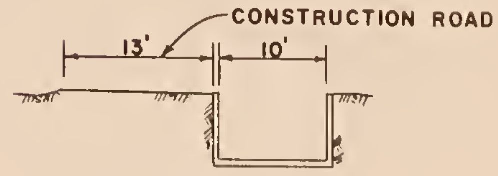


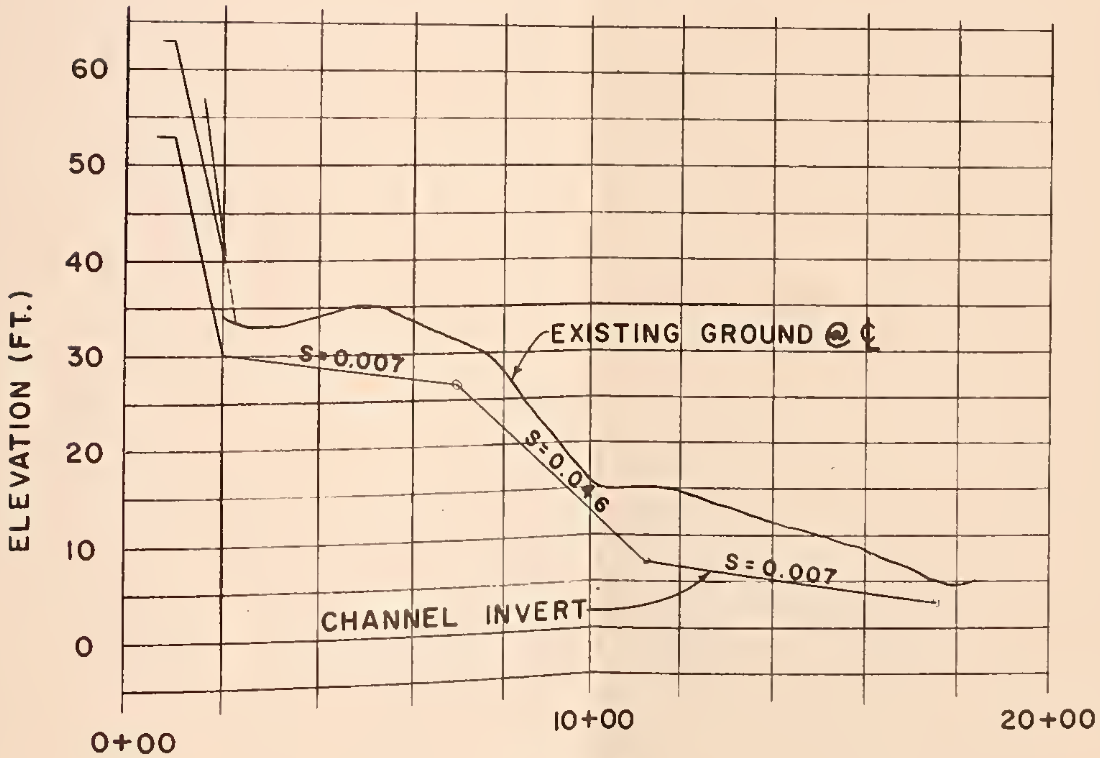


INLET
ISOMETRIC VIEW



STA. 2+05 TO 17+50

TYPICAL CROSS SECTION A-A



PROFILE

FIGURE 4
WORK PLAN
NAPILI 2-3 CHANNEL

HONOLUA WATERSHED

ISLAND OF MAUI, HAWAII

OCTOBER 1971

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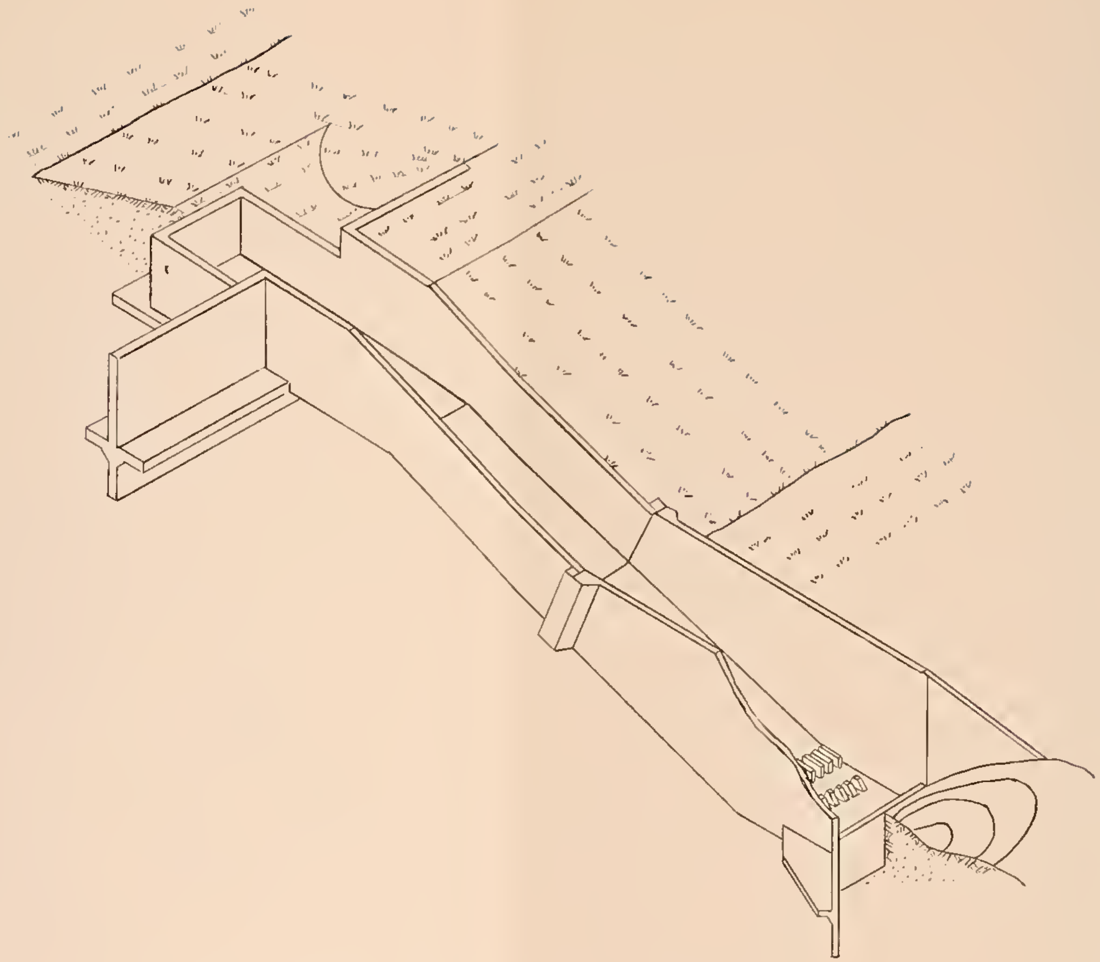
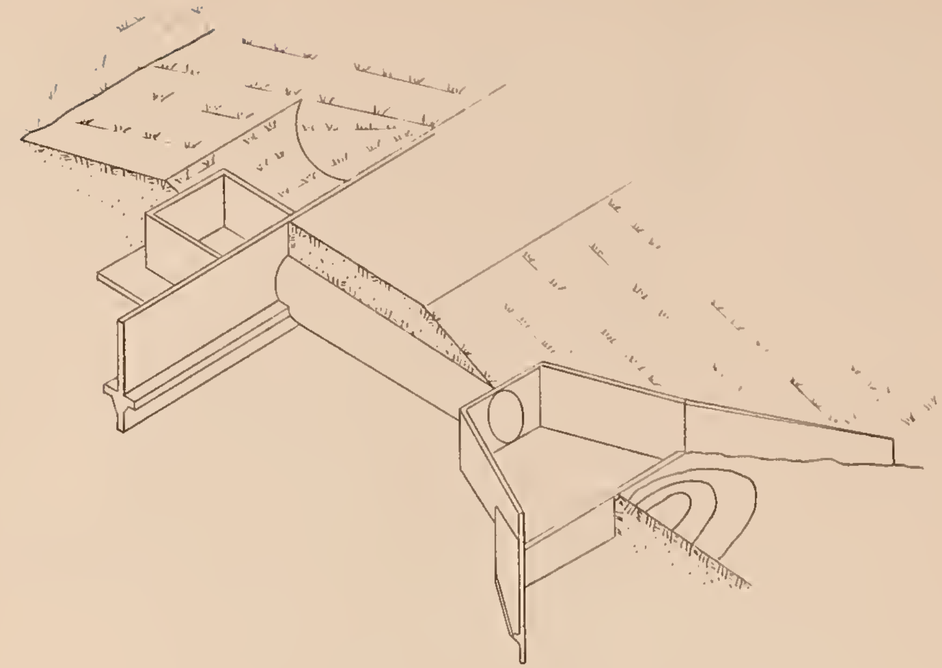


STRUCTURES NUMBERED 2, 3, 4 & 5

(NOT TO SCALE)



STRUCTURE NUMBER 6

(NOT TO SCALE)

FIGURE 5

WORK PLAN

TYPICAL SPILLWAY STRUCTURES

ISOMETRIC VIEWS

HONOLUA WATERSHED

ISLAND OF MAUI, HAWAII

OCTOBER 1971

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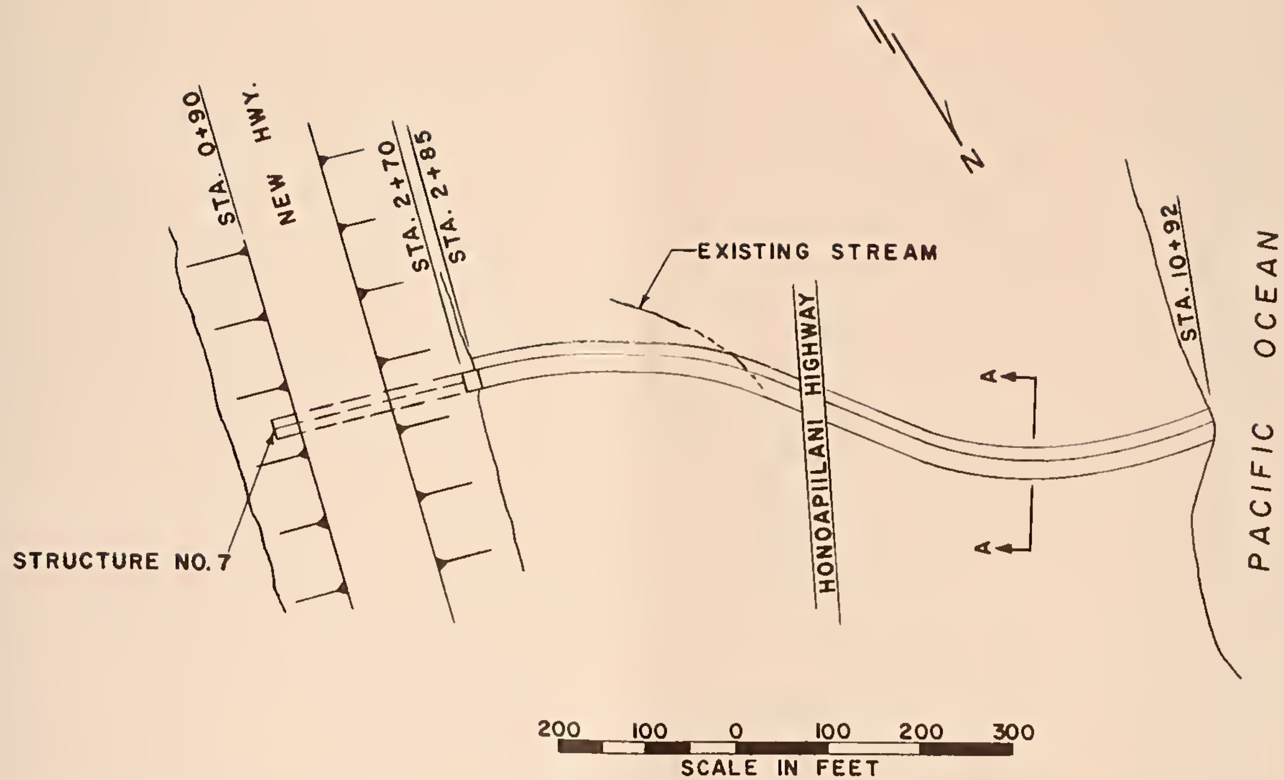
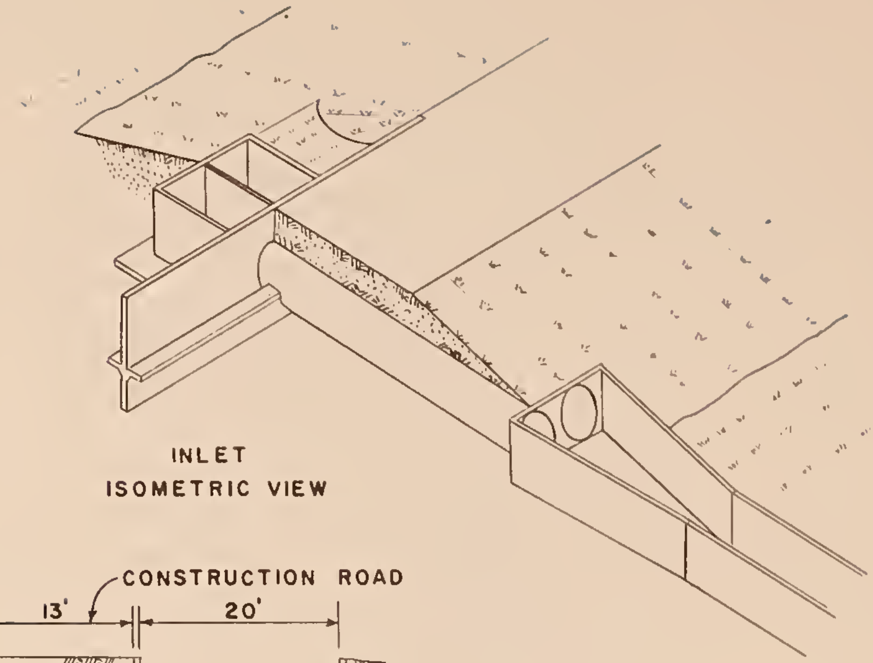
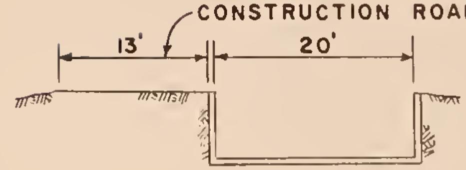


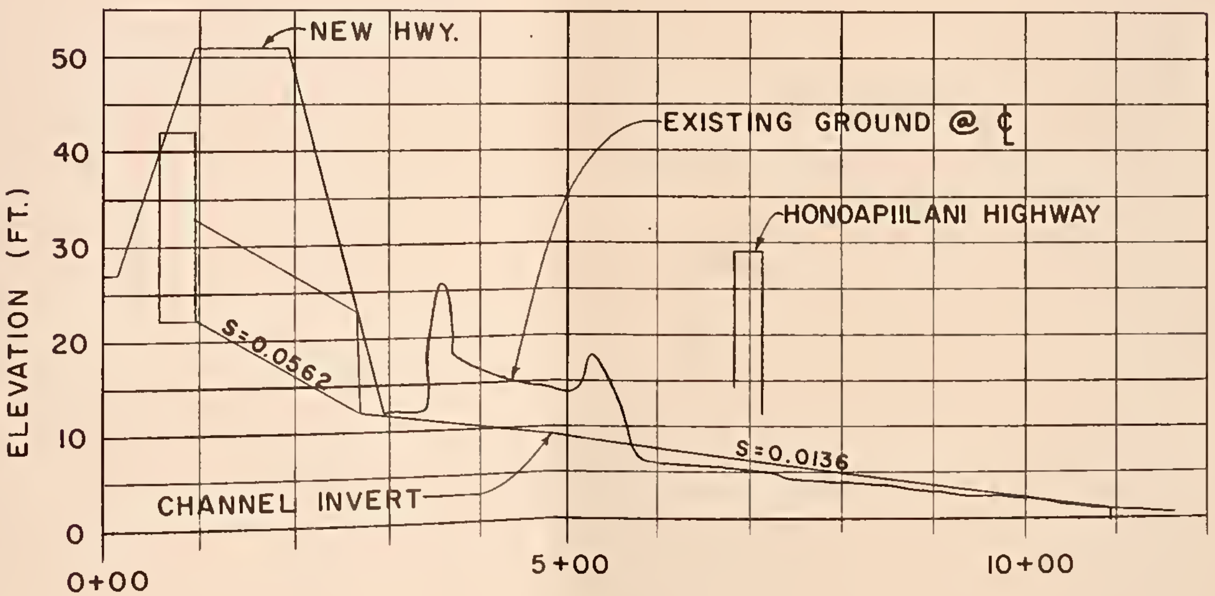


INLET
ISOMETRIC VIEW



STA. 2+85 TO 10+92

TYPICAL CROSS SECTION A-A



PROFILE

FIGURE 6
WORK PLAN
MAHINAHINA CHANNEL

HONOLUA WATERSHED

ISLAND OF MAUI, HAWAII

OCTOBER 1971

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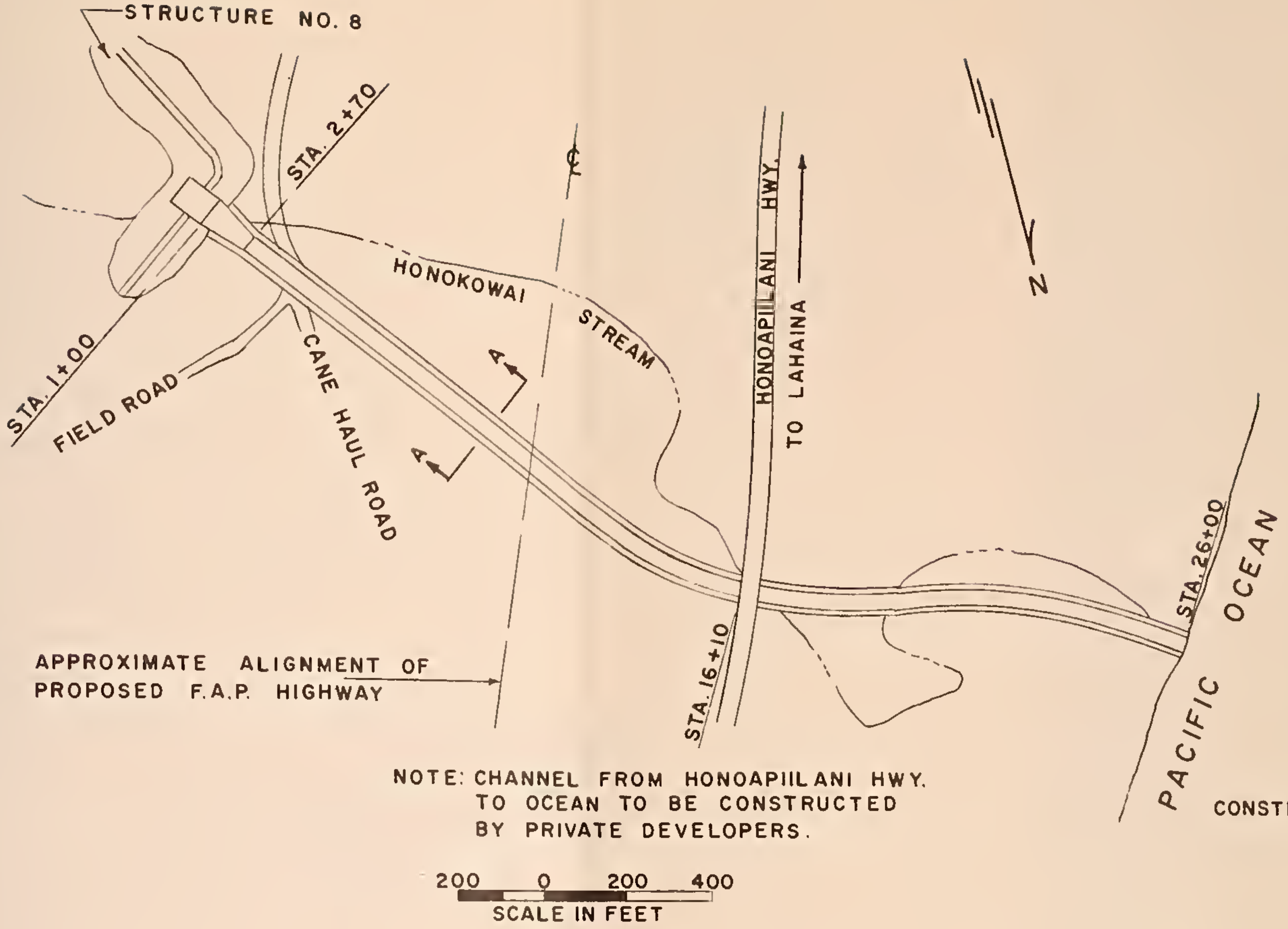
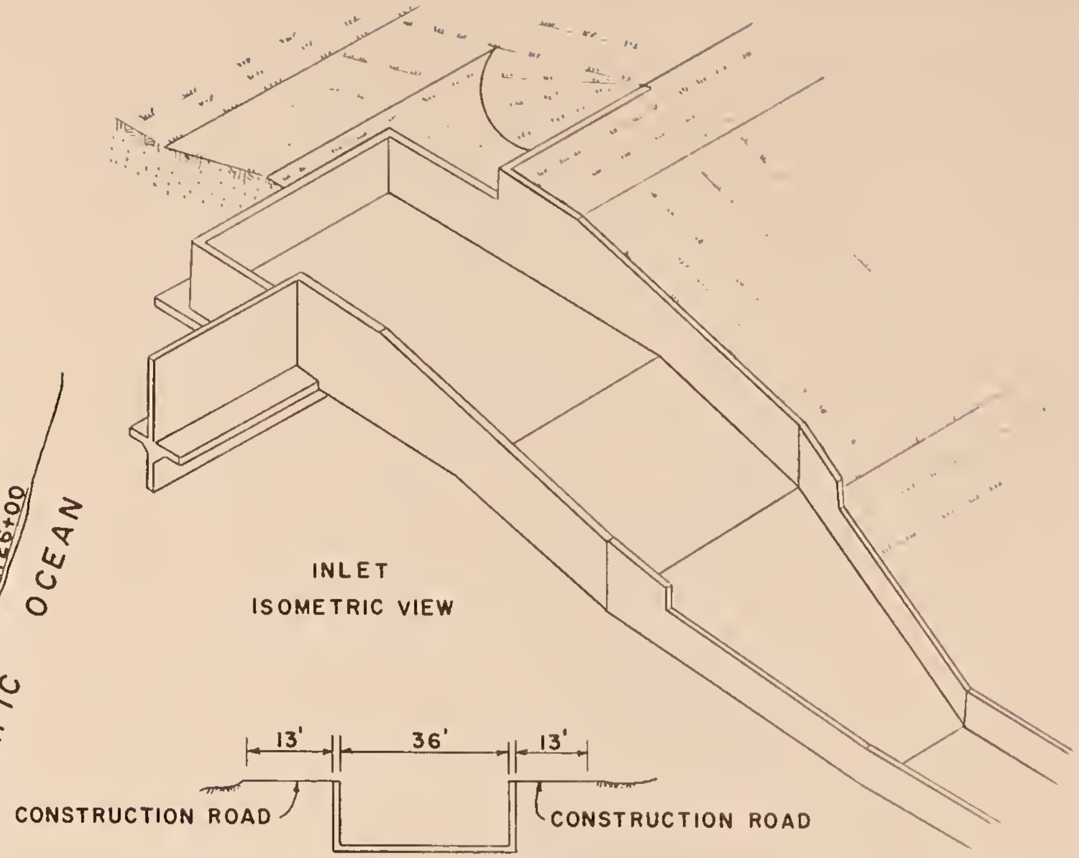
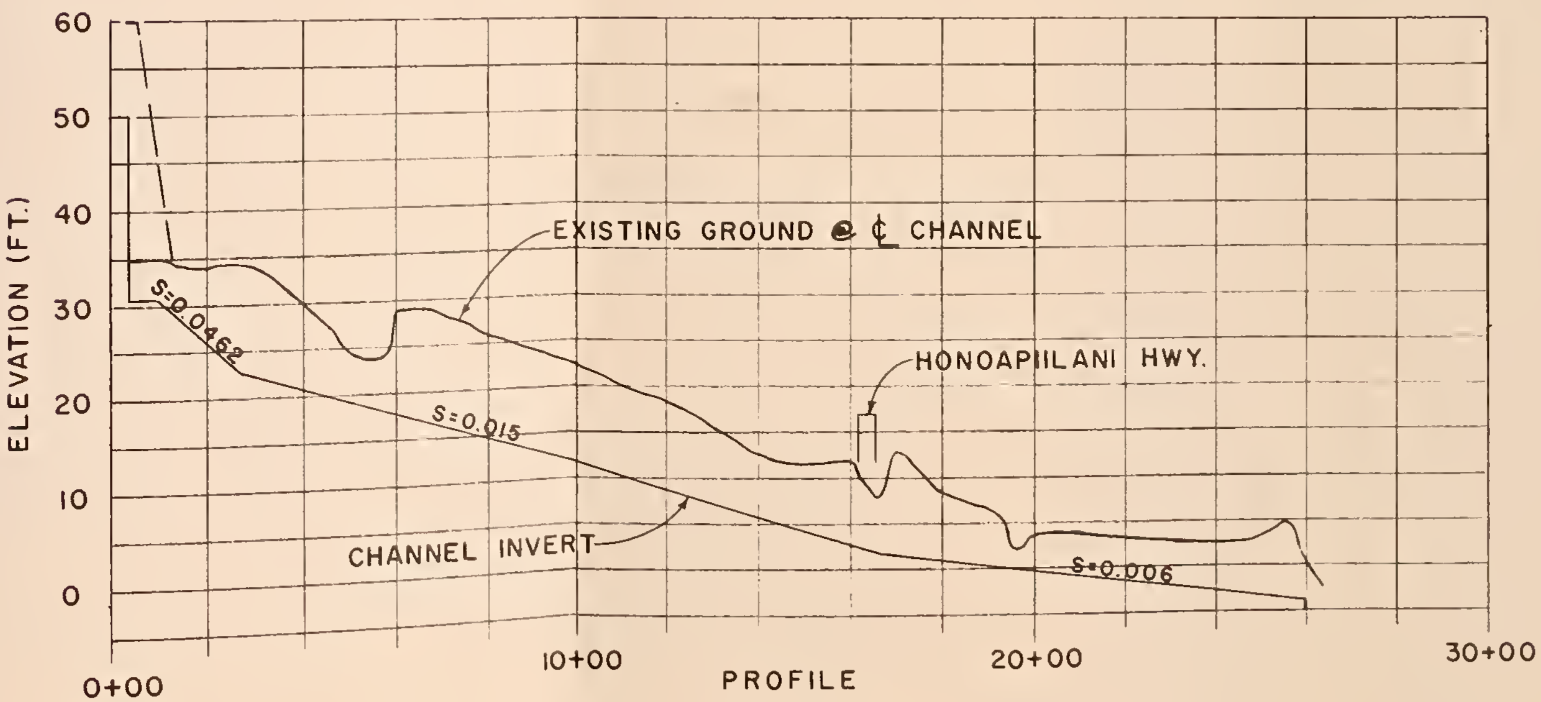




INLET
ISOMETRIC VIEW

STA. 2+70 TO 16+10
TYPICAL CROSS SECTION A-A



PROFILE

FIGURE 7
HONOKOWAI
HONOLUA WATERSHED
ISLAND OF MAUI, HAWAII
OCTOBER 1971

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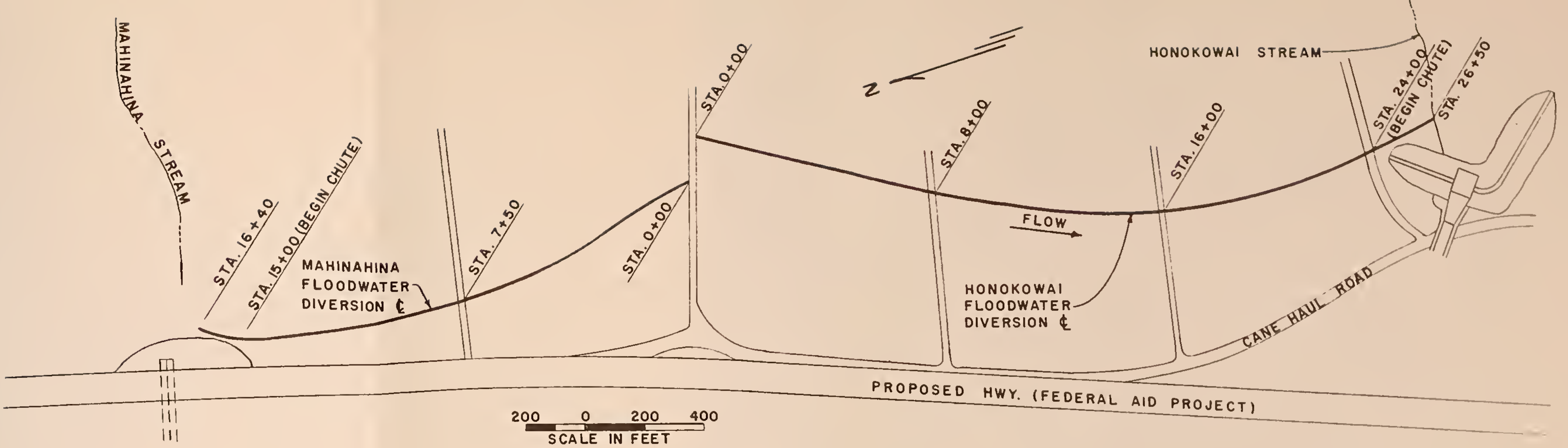
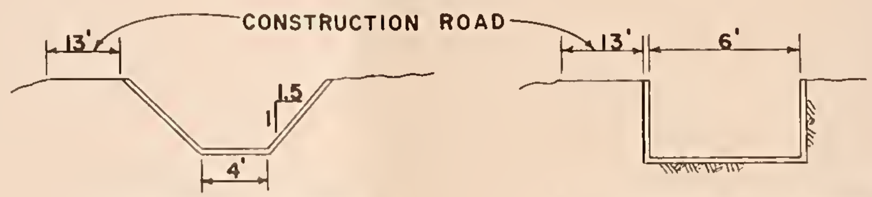
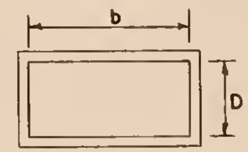




DIVERSION CHANNELS

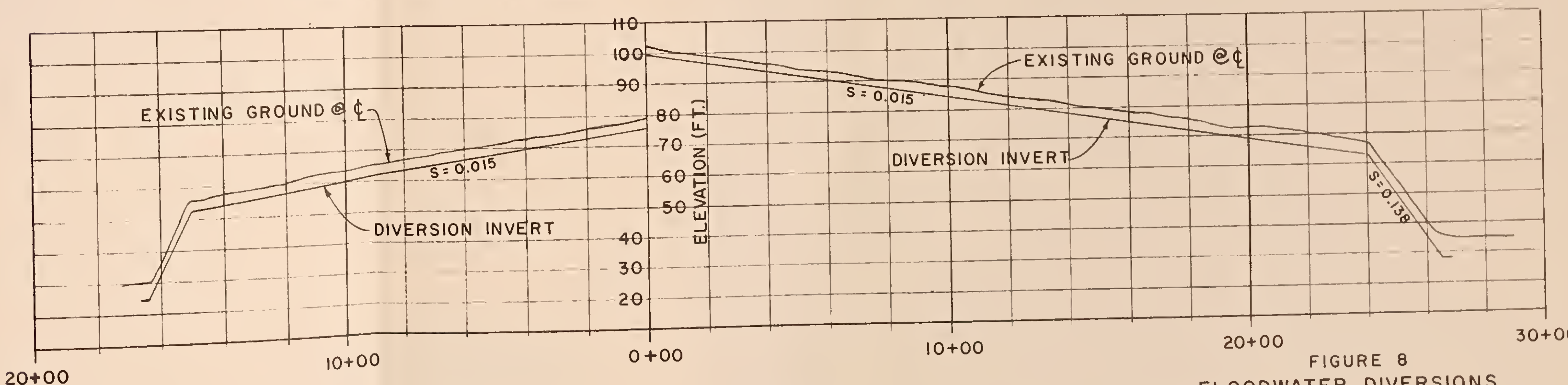
R/C CHUTES INTO GULCHES

TYPICAL CROSS SECTIONS



STA.	b (FT.)	D (FT.)
8+00	7.1	3.1
16+00	8.0	3.9
24+00	8.0	3.9

HONOKOWAI DIVERSION CULVERTS



PROFILE

FIGURE 8

FLOODWATER DIVERSIONS

HONOLUA WATERSHED

ISLAND OF MAUI, HAWAII

OCTOBER 1971

U.S. DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE

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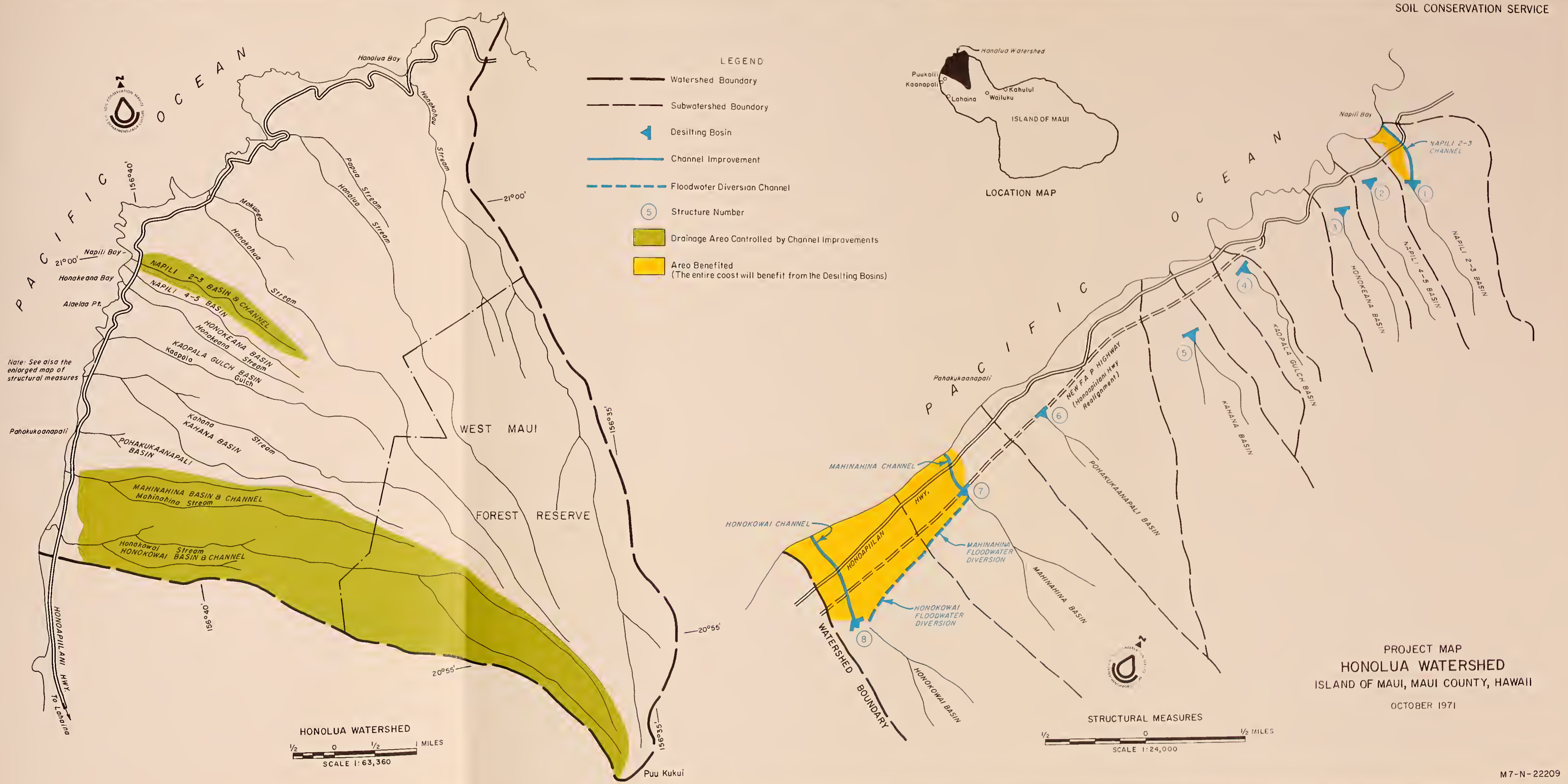
U. S. DEPARTMENT OF AGRICULTURE

SOIL CONSERVATION SERVICE



PROJECT MAP
HONOLUA WATERSHED
ISLAND OF MAUI, MAUI COUNTY, HAWAII
OCTOBER 1971

M7-N-22209

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